Andres Felipe Jaime Jaimes

A speculative perspective in the future of second-life electric vehicle batteries alternatives.

Master's thesis in Industrial Design
Supervisor: Casper Boks
Co-supervisor: Leander Spyridon Pantelatos
May 2023

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

NTNU
Norwegian University of
Science and Technology

Andres Felipe Jaime Jaimes

A speculative perspective in the future of second-life electric vehicle batteries alternatives.

Master's thesis in Industrial Design
Supervisor: Casper Boks
Co-supervisor: Leander Spyridon Pantelatos
May 2023

Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

NTNU
Norwegian University of
Science and Technology

NORSK-E

Acknowledgment

I would like to express my sincere gratitude to my supervisors, Casper Boks and Leander Spyridon, for their invaluable guidance, feedback, opinions, insights, discussions, and unwavering support throughout the entire project. I am also deeply appreciative of the experts I reached out to, who generously shared their knowledge and insights, helping me stay on track during the project's duration.

Moreover, I am immensely thankful to my families, who have been a constant source of encouragement and support throughout my Master's Degree journey. My mother Lina and sister Juliana deserve a special mention for their unwavering support during the project. My Norwegian family members, including Marianne, Eivind, Eira, mormor Helle, Vidar, Torbjørn, Thomas, Malin, Andrea, Malene, and Jørn, have been incredibly supportive, providing me with helpful advice and taking the time to listen to me talk about electric vehicle batteries and sustainability.

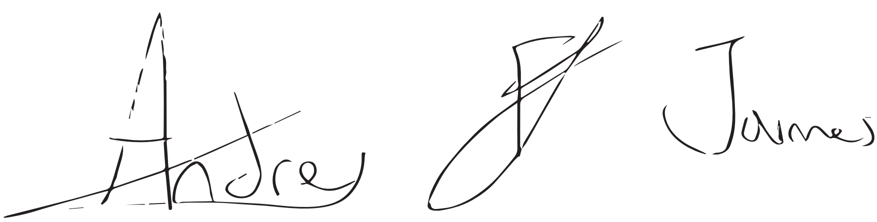
Lastly, I owe a debt of gratitude to my mother Lina, Marianne, and Eivind for their unwavering motivation and encouragement, which has enabled me to pursue this stage of my life. Without their support, this would not have been possible.

The Designer

Andres F. Jaime Jaimes
M. Sc. Industrial Design Student
B.S. Product Design

My passion for cars has always been linked to my interest in design. This led me to pursue a bachelor's degree in Product Design, where I discovered my passion for sustainability. I traveled to Norway to gain expertise in this area, where I worked on projects with sustainable objectives and assisted companies in transitioning to sustainable products or services.

This thesis project was quite interesting since it took me out of my comfort zone as a designer and united two of my greatest passions: cars and sustainability. Considering the problem that had to be tackled to generate a circular economy in one of the most relevant energy transitions worldwide, the batteries of electric vehicles. I designed a proposal to create applications for second uses for electric vehicle batteries that could be adapted to different contexts.



Preface

Before the development phase of this project, a pre-research proposal was conducted to evaluate possible second-life applications for electric vehicles batteries (EVB), which helped to narrow the application spectrum, highlight the future user needs or desires, and visualize the approach and methods that should be used in this project.

Surveys and unstructured interviews were conducted in the first half of the project that portrayed the position of some stakeholders in the EVB life cycle in Norway and Latin America. In addition, experts were also consulted about the scenarios proposed in the pre-research phase of the project, which produced insights about possible future user feedback and allowed me to follow a specific procedure in the speculative range.

Abstract

Summary
The transportation industry significantly impacts various aspects of daily life, including economic and environmental factors. However, it is also one of the most polluting activities. To address this issue, there is a growing need for sustainable alternatives such as Electric Vehicles (EVs) to achieve greener and more sustainable global mobility. While EVs are equipped with essential components known as Electric Vehicle Batteries (EVBs), they need to be removed from vehicles when they lose 20% or more of their capacity, according to manufacturers' guidelines. Although initial plans did not consider what to do with EVBs after they reached 80% capacity, increasing EVB retirements have raised concerns about their life cycle. However, with a good state of health (SOH), these batteries can be repurposed for other devices and applications to provide high-performance, low-environmental impact solutions. In addition, the emerging market is also creating new possibilities for innovative concepts based on used EV batteries that go beyond the EV industry.

Goal
This thesis aims to examine the various potential uses of used EVBs and how they can be adaptable to different situations and contribute to other forms of green energy conversion. This can extend the life of EVBs, delay the recycling process to improve the overall life cycle, and encourage a circular economy.

Methods
After conducting a pre-research project, it was determined that speculative design would be the best methodology for the process. Considering the immaturity of the market, I utilized forecast ideation and future concepts to visualize the insights I gathered and obtain feedback from companies. Throughout the process, I relied on ideation and data analysis.

Results
The outcome of this thesis is a product concept that aims to address sustainability concerns in the life cycle of EVBs and promote a circular economy. The concept focuses on three key components: branding, shell or container, and modularity, which would help generate repurposed activities for used EVBs and help grow new product ecosystems around them. All the product concepts resulted from gathered insights from web research, expert interviews, and valuable feedback from my supervisor.

Sammendrag

Bakgrunn
Transportindustrien påvirker ulike aspekter av dagliglivet, inkludert økonomiske og miljømessige faktorer. Imidlertid er den også en av de mest forurensende aktivitetene. For å takle dette problemet er det et økende behov for bærekraftige alternativer som elektriske kjøretøy (EV) for å oppnå grønnere og mer bærekraftig global mobilitet. Mens EV-er er utstyrt med viktige komponenter kjent som elektriske kjøretøysbatterier (EVB-er), må de fjernes fra kjøretøyet når de mister 20% eller mer av kapasiteten sin, i henhold til produsentenes retningslinjer. Selv om de opprinnelige planene ikke tok hensyn til hva man skulle gjøre med EVB-er etter at de nådde 80% kapasitet, har økende antall utrangerte EVB-er skapt bekymringer for deres livssyklus. Imidlertid kan disse batteriene, med god helsetilstand (SOH), bli gjenbrukt i applikasjoner for å tilby høy ytelse og lav miljøpåvirkning. I tillegg skaper det voksende markedet også nye muligheter for innovative konsepter basert på brukte EV-batterier, også utenfor EV-industrien.

Mål
Denne avhandlingen har som mål å undersøke de ulike potensielle bruksområdene til brukte EVB-er og hvordan de kan tilpasses ulike situasjoner og bidra til andre former for grønn energiomforming. Dette kan forlenge levetiden til EVB-er, utsette gjenvinningsprosessen for å forbedre den totale livssyklusen og fremme en sirkulær økonomi.

Metoder
Etter å ha gjennomført et forprosjekt ble det bestemt at spekulativ design ville være den beste metodikken for prosessen. Med tanke på at dette markedet er såpass nytt, benyttet jeg prognosebasert idémyldring og fremtidige konsepter for å visualisere innsiktene jeg samlet inn og få tilbakemeldinger fra selskaper. Gjennom hele prosessen støttet jeg meg på idémyldring og dataanalyse.

Resultater
Resultatet av denne avhandlingen er et produktkonsept som tar sikte på å adressere bærekraftsutfordringer i livssyklusen til EVB-er og fremme en sirkulær økonomi. Konseptet fokuserer på tre nøkkelkomponenter: merkevare, beholder/container og modularitet, som ikke bare vil bidra til å generere gjenbruk av brukte EVB-er, men også hjelpe til med å skape nye produktøkosystemer rundt dem. Alle produktkonseptene ble utviklet basert på innsikt fra nettbasert forskning, intervjuer med eksperter og verdifulle tilbakemeldinger fra veilederen min.

NTNU
Fakultet for arkitektur og design
Institutt for design

Masteroppgave for student Andres Felipe Jaime Jaimes

Title Design of a product based on repurposed EV batteries.

This project aims to explore the potential for a product based on scalable repurpose alternatives for used EV batteries that could be used, versatile in other contexts, and adaptable to different scenarios.

Bakgrunn og formål med oppgaven

The transport industry plays an essential role worldwide, impacting various daily life parameters, including economic and environmental facets. Being one of the most pollutant activities, the urge for sustainable alternatives to mitigate the environmental burden caused by vehicles has positioned Electric Vehicles (EVs) as the short and long-term future strategy to achieve greener and more sustainable global mobility. Although manufacturers consider batteries unsuitable for use in electric vehicle powertrains after losing 20% or more of their original capacity, they still have a good state of health (SOH) to adapt in various other contexts to be used in devices, activities and applications provide high-performance, low environmental impact solutions for less demanding applications. The immaturity of the market allows exploring new possibilities for new concepts based on used EV batteries, in scenarios and markets other than the EV industry.

Forventet tilnærming

1. Analysis of existing solutions and state-of-the-art in different contexts.
2. Analysis of potential application areas/scenarios into which it could be adapted.
3. Analysis of variables/determinants that must be adapted depending on the chosen application.
4. Meeting with stakeholders and experts to evaluate the analysis.
5. Choice of direction.
6. Develop concepts based on the direction chosen.
7. Collect feedback that would lead to the final concept.
8. Present concepts for a prototype.
9. Prototype of the final concept (if time and resources permit).

Oppgaven utføres etter "Retningslinjer for masteroppgaver i Industriell design".
Hovedveileder: Casper Boks
Biveileder: Leander Spyridon Pantelatos

Utleveringsdato: 9. januar 2023 Innleveringsfrist: 29. mai 2023

NTNU, Trondheim, 09.Januar 2023

Casper Boks
Veileder

Sara Brinch
Instituttleder

List of Abbreviations

BMS – Battery management system
B2U – Battery second use
CRM – Critical raw materials
EOL - End of life
ESS – Energy Storage System
EV – Electric Vehicle
EVB – Electric Vehicle Battery
ICE – Internal combustion Engine
LCA – Life cycle analysis
LIB – Lithium-ion Battery
OEM – Original equipment manufactured
SOH – State of health
V1G – Vehicle to grid 1.0 (smart charging)
V2G – Vehicle to Grid 2.0

Deliver

Discuss

1. Background

As the world shifts towards cleaner energy sources, the transport industry has turned to electric vehicles as a viable solution. The growing concern for reducing the negative impact of mobile sources on the environment has led to a rapid increase in the use of EVs on roads, resulting in a significant demand in the transport market. According to Inc. (Inc., 2021), countries such as Norway, the USA, and China are expected to witness a rise in EV usage, with estimates suggesting an 80% growth by 2040 from a current 10% in 2022. However, the mass production of these new technologies has brought about mid-term and long-term problems that were not initially considered during their development and adaptation.

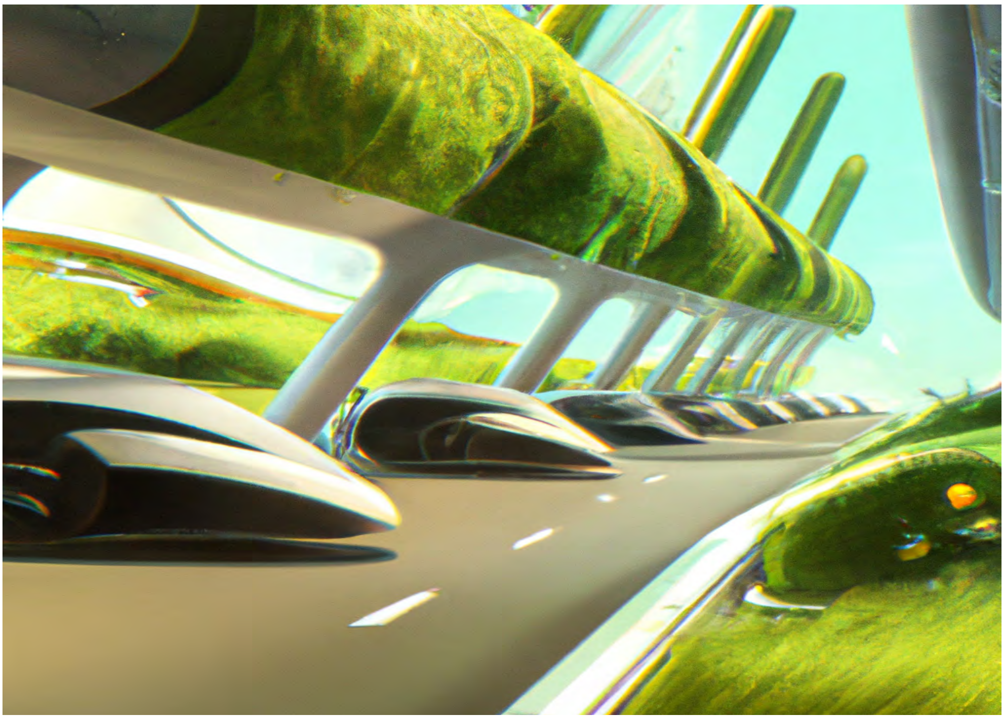


Figure 1. Image generated by AI with keywords future and mobility – Open source

EV Batteries

As the transport industry shifts towards green energy, Electric Vehicle (EV) batteries are vital in this transition. The success of upcoming EV models relies heavily on battery and engine optimization advancements. These batteries are crucial throughout the EV's lifespan, as they are responsible for energy storage, capacity, range, and performance. To ensure the successful adoption of electric vehicles, it is imperative to focus on maintaining and improving battery technology.

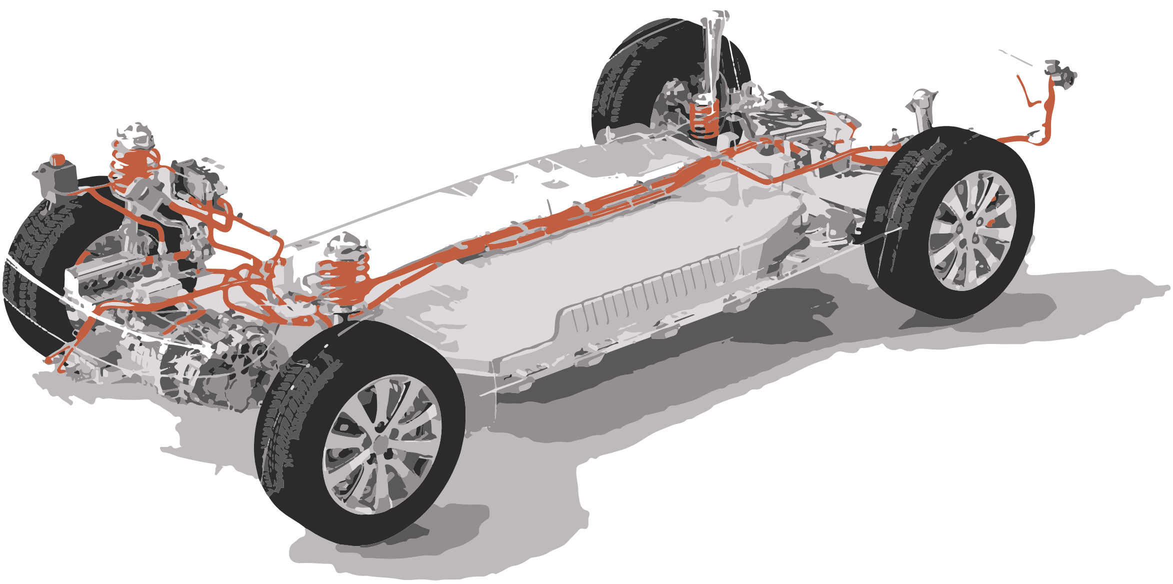


Figure 2. Illustration made form intervention of a picutre taken by PhonlamaiPhoto, 2022 via www.pixxabay.com

Several factors differentiate battery packs, such as size, modularity, maturity, cooling properties, and Battery Management System (BMS) type. However, battery packs can be classified based on cell type and chemistry. Cell types fall into three categories: Cylindrical, Prismatic, and Pouch. Cylindrical cells have good mechanical properties and lower manufacturing costs. Prismatic cells offer better thermal management and higher power/energy delivery ratios than cylindrical cells with the same volume. Pouch cells are ideal for micro-mobility vehicles, short-range, or hybrid vehicles, as they offer better power and space optimization, but their energy storage capacity is not suitable for long-range vehicles. (Melançon, 2022, Kampker et al., 2016)

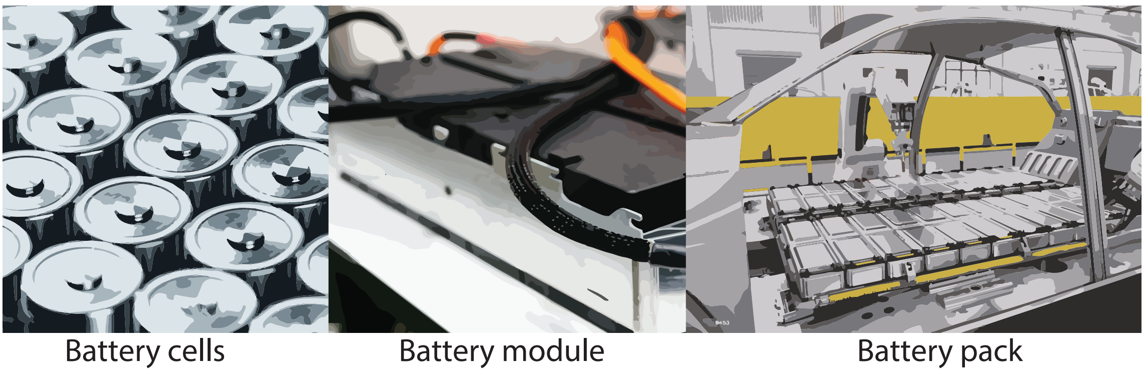


Figure 3. Illustration made from the intervention of pictures taken by Just_Super, 2022; Supersmario, 2018; PhonlamaiPhoto, 2023. via www.pexxels.com

Battery pack modules differ among manufacturers and are tailored to each EV model for optimal energy density, installation, maintenance, and isolation. Incorporating modularity in a battery pack allows for easy maintenance and isolation, which reduces the risk of damage spreading to other sections of the battery pack in case of an accident. (Kampker et al., 2016)

Battery Pack

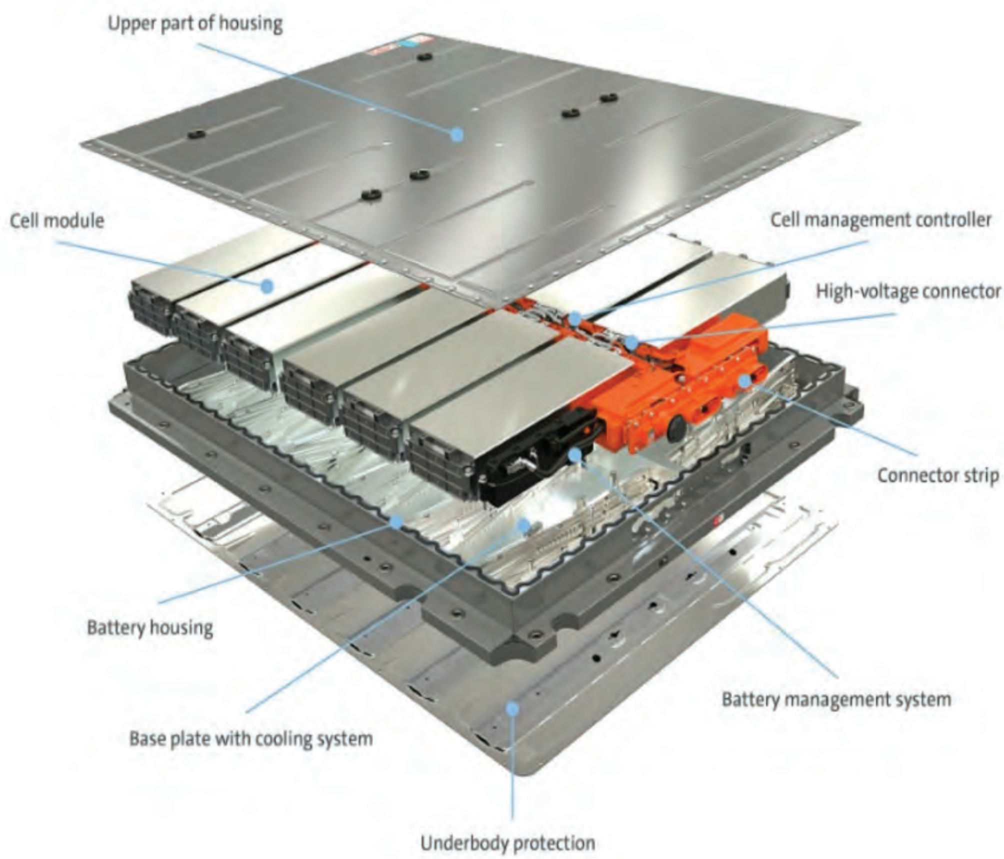


Figure 4. The components of the MEB battery system - Image taken from © 2023 Volkswagen of America, Inc https://www.vw.com/en/newsroom/everything-electric/batteries.html

Life Cycle

The life cycle of an electric vehicle (EV) battery was initially only considered for meeting the needs of the first wave of EVs, without any thought given to what would happen after the battery was retired. However, repurposing these batteries presents an opportunity to develop strategies for generating and transporting energy in remote areas with limited access to energy, thereby reducing the reliance on fossil fuels.

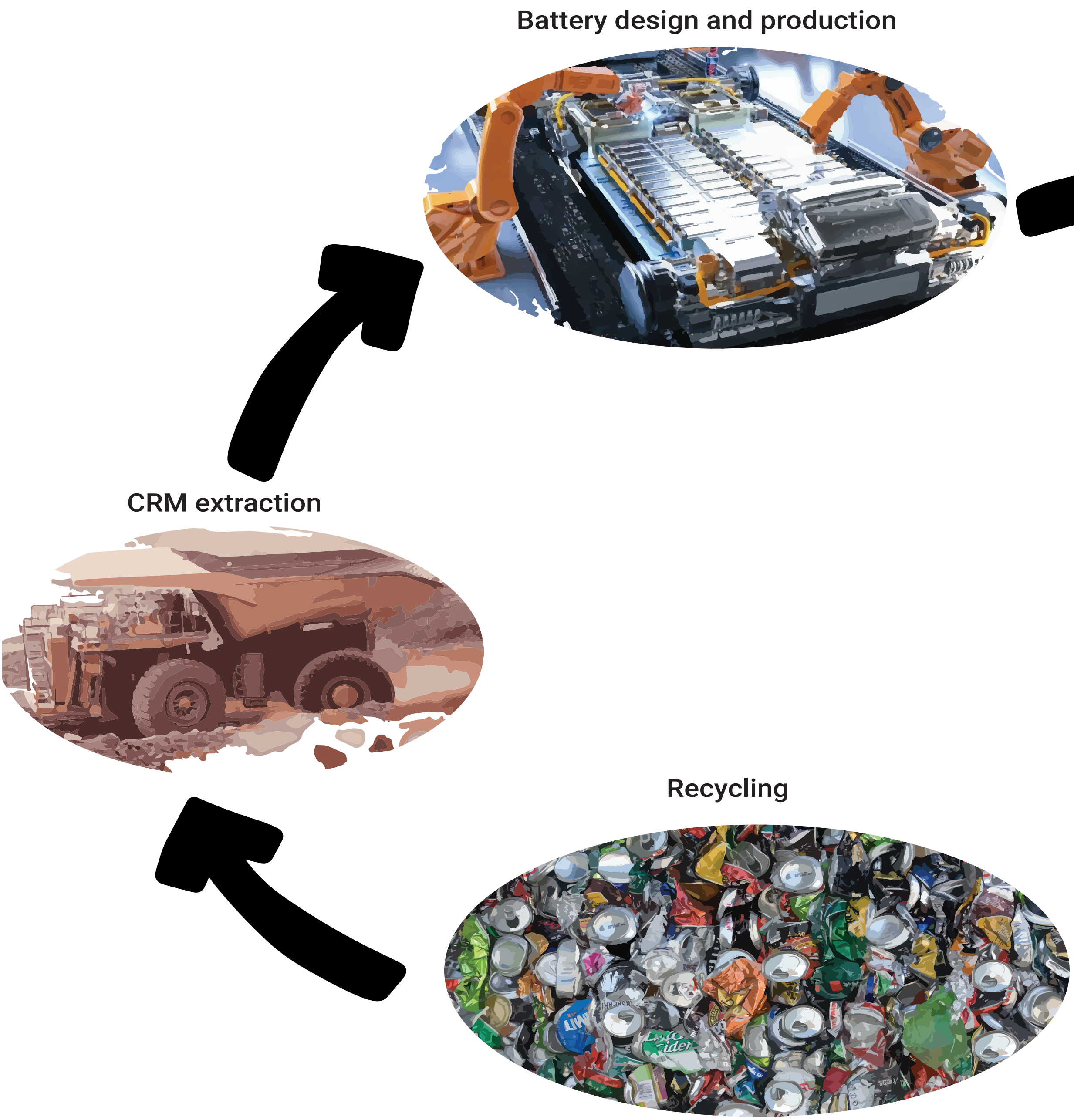
The life cycle of an EV battery includes several stages, such as raw materials extraction, planning and design, manufacturing, maturity, decline, and end-of-life (EOL). However, structured recycling processes or second-use applications for retired batteries were not previously considered, even though these batteries still retain between 70% to 80% of their capacity, which could be utilized in activities requiring less battery capacity.

EV batteries typically have a lifespan of 8 to 10 years and between 1,000 to 3,000 charging cycles, depending on usage and user behavior (Faria et al., 2014). Previously, retirements were viewed as a mid-term process, with no further stages considered once the battery was removed from the propulsion system. However, as vehicles produced in the early 2010s begin reaching the end of their lifespan, new strategies for repurposing and recycling EV batteries need to be developed to meet the increasing demand for new vehicles.

Introducing repurposing applications for retired EV batteries would reduce the need for new battery production, allowing the remaining capacity of these batteries to be utilized in various scenarios, including generating energy storage systems (ESS) for different clean energy sources, as part of the green energy transition strategy. Additionally, this would reduce the burden on the environment from producing new EV batteries while also providing companies with more time to develop and refine their refurbishing and recycling processes, which can be automated for safety, standardization, and cost reduction purposes in the industry, thereby creating more affordable reuse applications.

EVB Life cycle

Contemplated in early stages of EVB scope



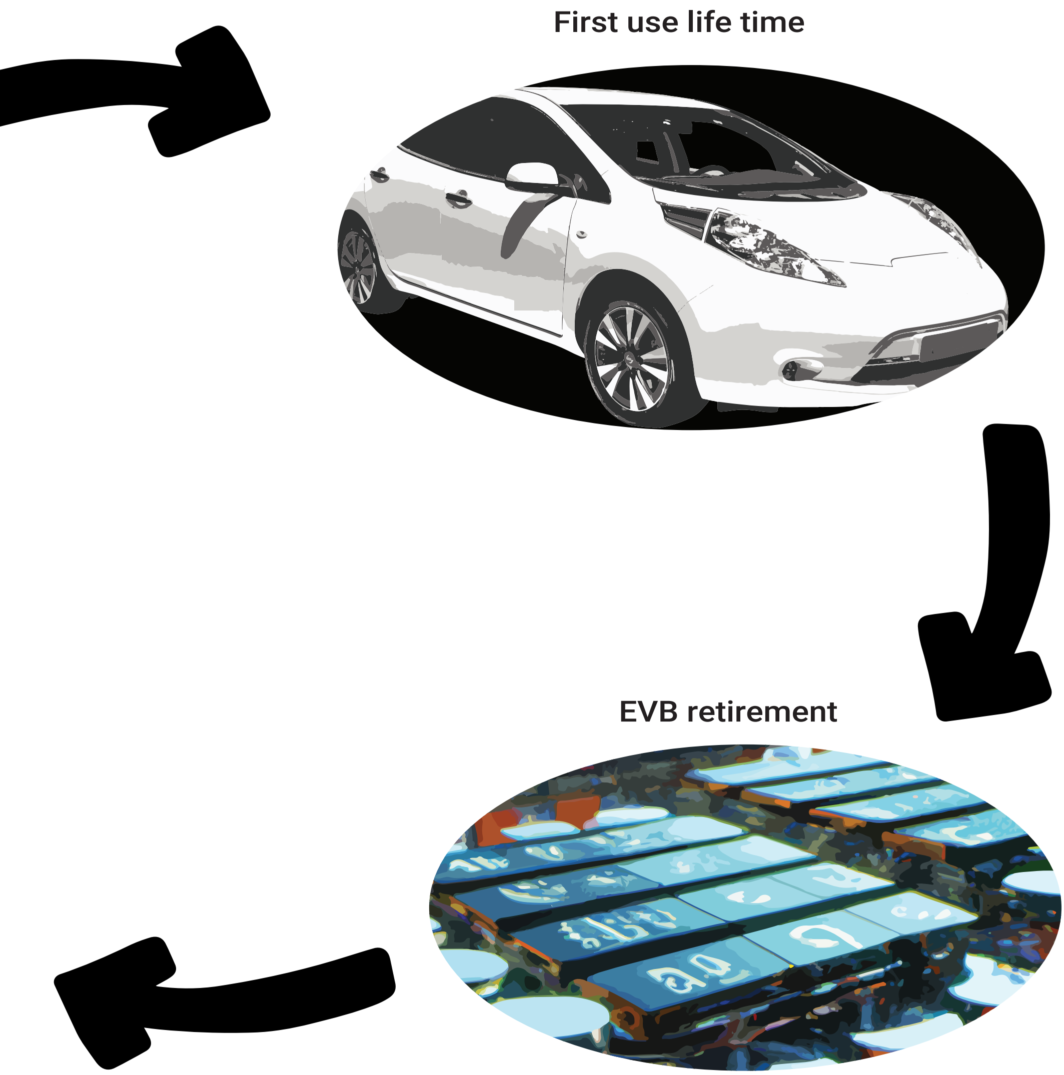
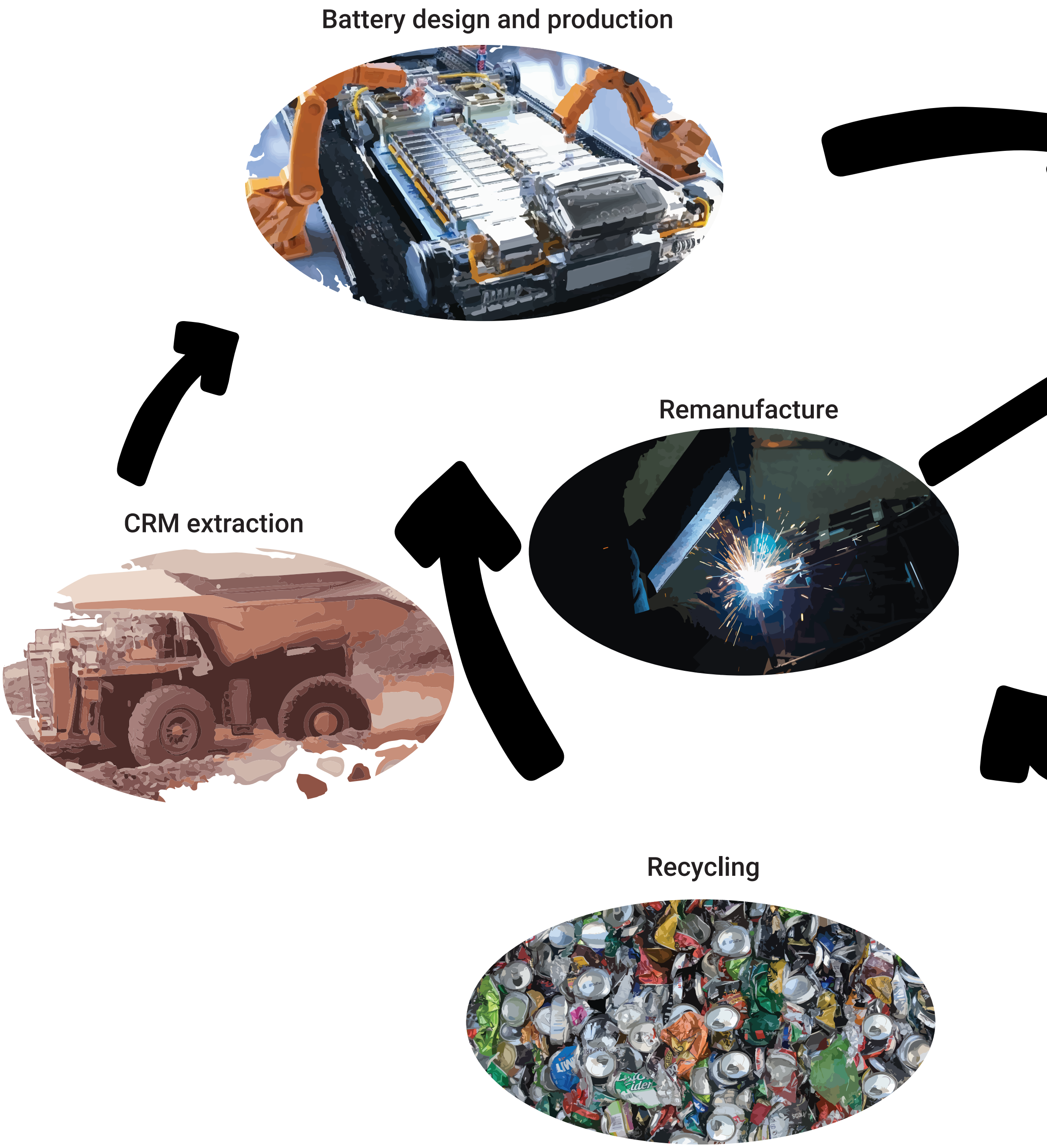


Figure 4. Graphic made by autor from images open source 2023, via www.pexxels.com

EVB Life cycle aiming circular economy



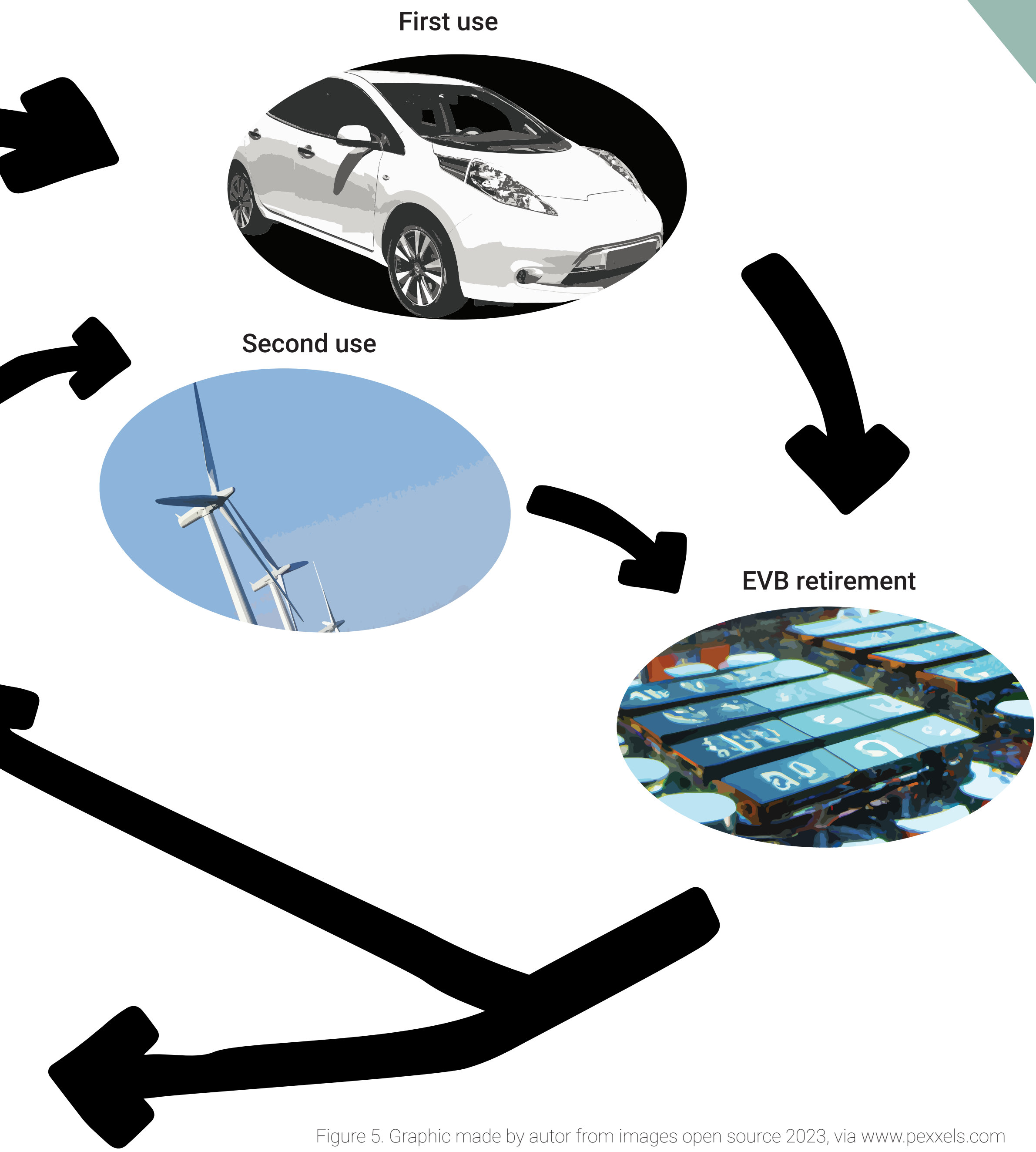


Figure 5. Graphic made by autor from images open source 2023, via www.pexxels.com

Sustainability dilemma

The transport industry's shift towards Green Energy is expected to alleviate the environmental impact caused by this sector. Although EVs are deemed more energy-efficient than ICE vehicles, transferring a minimum of 90% of energy to the drive train, they are still not entirely sustainable. Several factors, such as the extraction of scarce raw materials, planned obsolescence due to energy capacity loss, production scaling corresponding to demand, and the need to meet sustainability goals for 2030 and zero waste for 2050, affect the entire life cycle.

According to Life Cycle Analysis (LCA), EV batteries constitute almost 40% of the environmental burden during their production phase (Girardi et al., 2015, Kotak et al., 2021). The increasing demand for Critical Raw Materials (CRM) to supply the battery requirements creates uncertainty among stakeholders regarding the EVB life cycle. There are debates over recycling by losing all the potential and capacity remaining in batteries but recovering CRM for new batteries or repurposing batteries to slow down the production of new batteries for other activities. This gives recycling companies time to refine their processes to fully utilize the potential of battery materials and capacity by expanding the EOL stage.

To achieve a closed cycle in the circular economy of EVBs, the USA and Europe are establishing new laws to create a fully sustainable life cycle, including the acquisition, usability, and recollection of CRM. Companies in the value chain could aim to repurpose and mitigate sustainable gaps in the cycle when EVBs are discarded or directly recycled after their first use in an EV.

Sustainable Goals

By repurposing an EVB, not only can a circular economy and zero waste goals be achieved throughout its entire lifespan, but also make significant contributions towards achieving the sustainability goals set by the EU and United Nations for 2030. By exploring innovative applications and activities within this niche, we have the potential to create a new industry that fosters partnerships for clean energy storage and energy networks in remote areas and communities, thereby fulfilling their basic needs. Additionally, such applications can promote educational schemes that encourage responsible consumption and ultimately lead to the development of sustainable communities.

Figure 6. Image taken from UN sustainable goals, 2023, via https://sdgs.un.org/goals

Actual situation and forecast

Electric vehicle production has been increasing steadily to meet global energy transition and sustainability goals. In the last decade, production has soared by over 100%, with plug-in vehicle sales expected to rise from 6.6 million in 2021 to 20.6 million in 2025. (AGENCY, 2022, Inc., 2021)

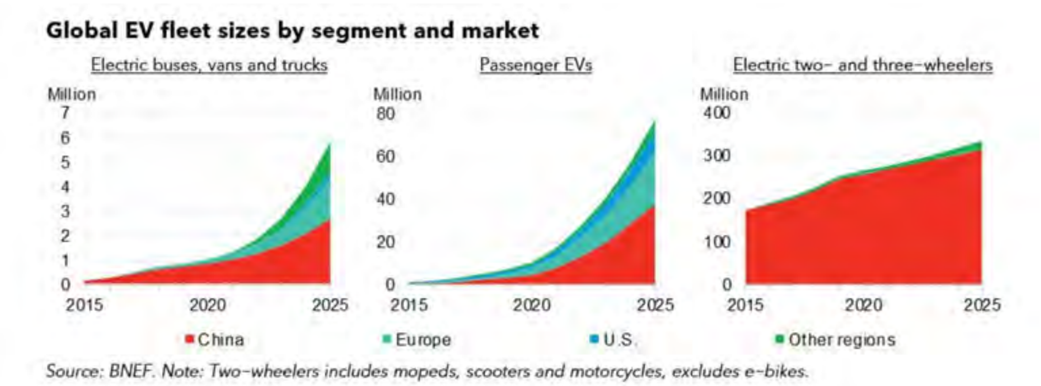


Figure 7. Graph taken from BloombergNEF 2022 Electric Vehicle Outolook, 2023 via https://about.bnef.com/electric-vehicle-outlook/

As the years go by, the number of retired EV batteries increases exponentially. Vehicles sold ten years ago have reached the minimum percentage declared by manufacturers and need to be replaced or retired from the road. This figure is expected to climb from 1 million retired batteries annually by 2024 to 6 million by 2030. It is crucial to address this issue now to prevent further environmental damage caused by the EV industry. (IDTECHEX, 2023)

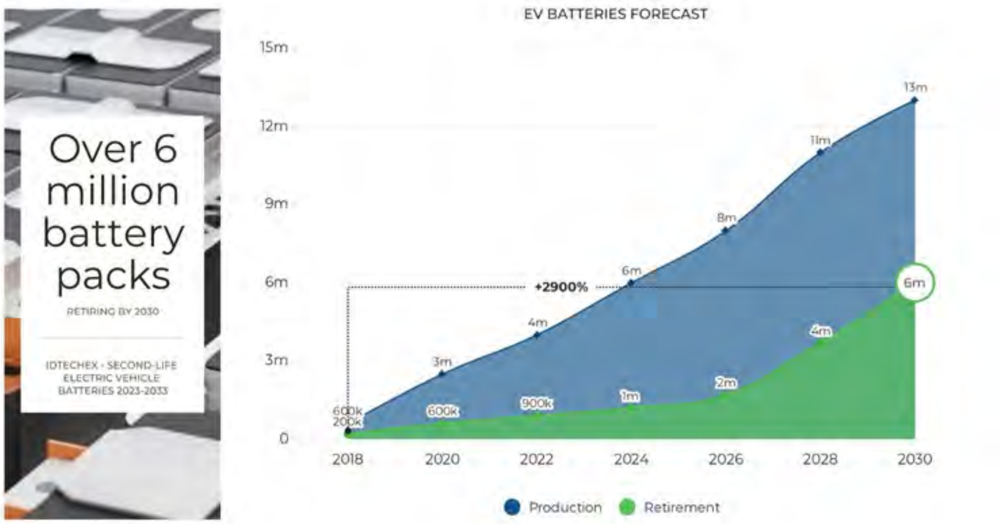


Figure 8. Graph by autor from imformation gathered from IDTECHEX Second-life Electric Vehicle Batteries 2023-2033 outlook, via https://www.idtechex.com/en/research-report/second-life-electric-vehicle-batteries-2023-2033/924

Forecasting companies such as Spark from Volue, a company specializing in green transitions and EV integration into smart charging V1G or Vehicle to Grid V2G, predict that by 2030, over 800,000 energy storage systems will be integrated into grids and off-grid applications worldwide. This presents an opportunity for B2U to follow suit and add value to the chain.

Energy forecasts indicate that second-life batteries' capacity will reach over 280GWh annually by 2030. This potential can be leveraged to repurpose EVBs into energy storage systems that can store and transport clean energy from green sources, including other industries' energy transition.

Standard UL1974

Once Electric Vehicle Batteries (EVBs) reach their capacity limit established by manufacturers, they must undergo a series of processes. Each battery must be evaluated individually as each one has been exposed to different user behaviors, charging schemes, and conditions during its life span in a propulsion system.
Used EVBs must comply with the safety standard set by UL1974, which was developed to ensure their state of health, capacity, and whether they can be repurposed or need to be recycled. Additionally, if these used EVBs are to be converted into stationary Energy Storage Systems (ESS), they must also follow other safety standards such as UL1973.

As of current research, only 4R Energy (Japan's venture between Nissan and Sumitomo Corp.) has received standard certification for their B2U applications.

State of the art

The use of second-life batteries has the potential to drastically alter the value chain of EV stakeholders and energy sectors, offering benefits to the energy transition and future infrastructure. This could lead to the development of a circular economy for the life cycle of EV batteries, ultimately resulting in increased desirability and profitability over new batteries in the long term.

Although B2U strategies are still in their early stages and the market is not yet mature, some manufacturing companies have already begun creating projects or partnering with other stakeholders to utilize OEM parts and create stronger identities for these initiatives. Other companies have formed partnerships with stakeholders throughout the product life cycle to develop new product lines, with each company focusing on their specialties.

One of the main focuses for repurposing electric vehicle batteries (EVB) is the creation of Energy Storage Systems (ESS). ESS presents an excellent opportunity to transition to renewable energy grids, enhance grid and off-grid applications, store energy from different sources, and be a backup during emergencies. ESS is widely used in households as battery packs and on a larger scale in stadiums and other industrial settings.

Nissan's sub-brand, 4R Energy, has been testing and adapting used EVB to create scalable ESS using Nissan Leaf batteries, one of the first EVs produced on a large scale. Their repurposing activities include developing household applications, off-grid lighting, and transforming the Ajax Stadium (Amsterdam Arena) grid in Amsterdam. They have also launched a specialized project called Blue Switch, focused on providing energy for emergencies, such as natural disasters in Japan.

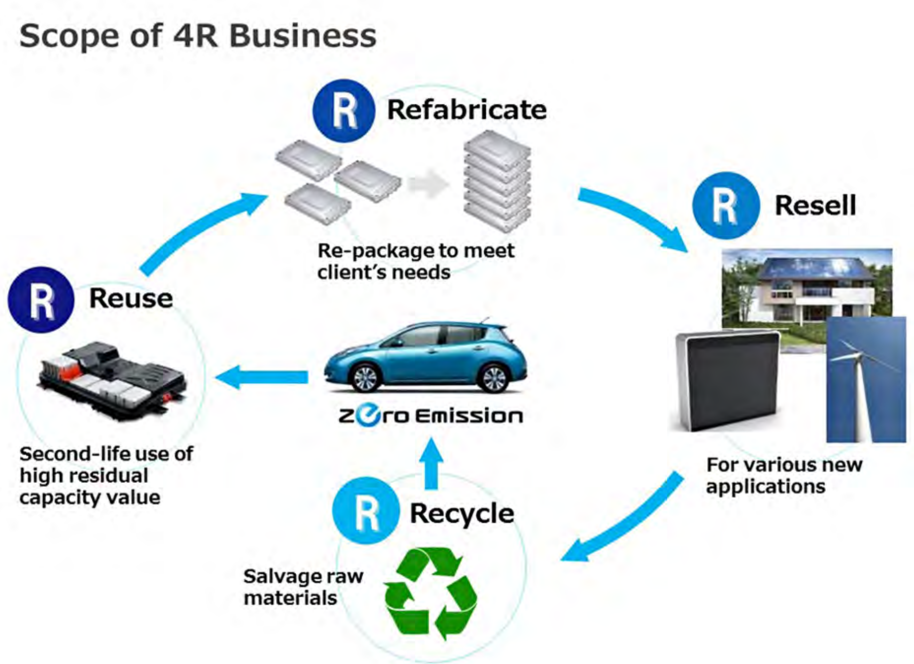


Figure 9. Image taken form Nissan stories, 2023 via https://global.nissanstories.com/en/releases/4r

Battery manufacturer, EATON, has partnered with car manufacturers like Nissan to create large-scale ESS for Ullevål Stadium in Oslo, Norway. They also focus on patenting and implementing B2U in the US and Chile. Mostly using battery packs from Nissan leaf, as it was one of the first EV mass produced.

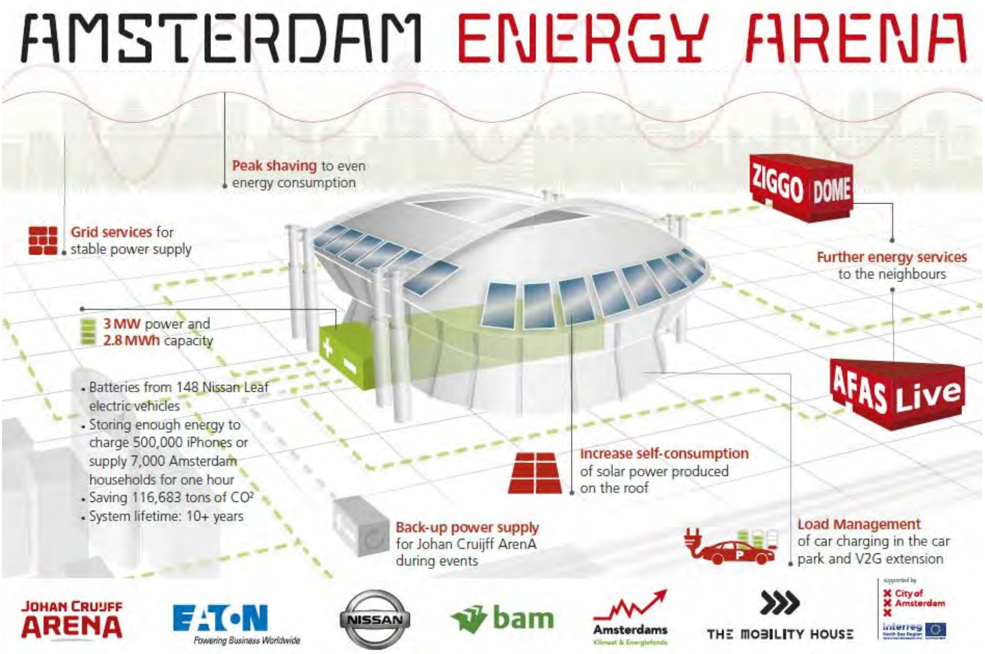


Figure 10. Image taken form Nissan stories, 2023 via https://global.nissanstories.com/en/releas-es/4r

Several car manufacturers, including Volkswagen, Toyota, Renault, BMW, and Daimler, are actively seeking ways to repurpose electric vehicle batteries after their initial use. These companies are exploring the potential of vehicle-to-grid (V2G) technology, which would allow them to use these batteries to store energy for future use, including charging other EVs and powering households. Volkswagen is even investing in “mobile power banks” to provide charging stations in any location.

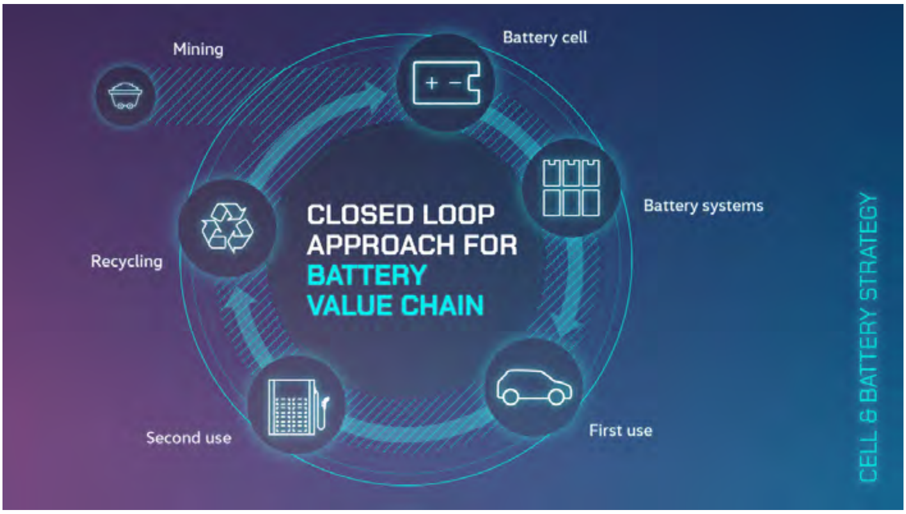


Figure 11. Image taken form Volskwagen group, 2023 via https://www.volkswagenag.com/en/strategy/battery-charging.html#

Figure 12. Image taken form Volskwagen design, 2023 via https://www.volkswagenag.com/en/sustainability/decarbonization/life-cycle.html

One company, Relectrify, has developed a new battery management system (BMS) that can individually control each module or cell, thus optimizing power and capacity depending on the energy needs of the moment. This technology has shown a 30% increase in the lifespan of used EVBs.

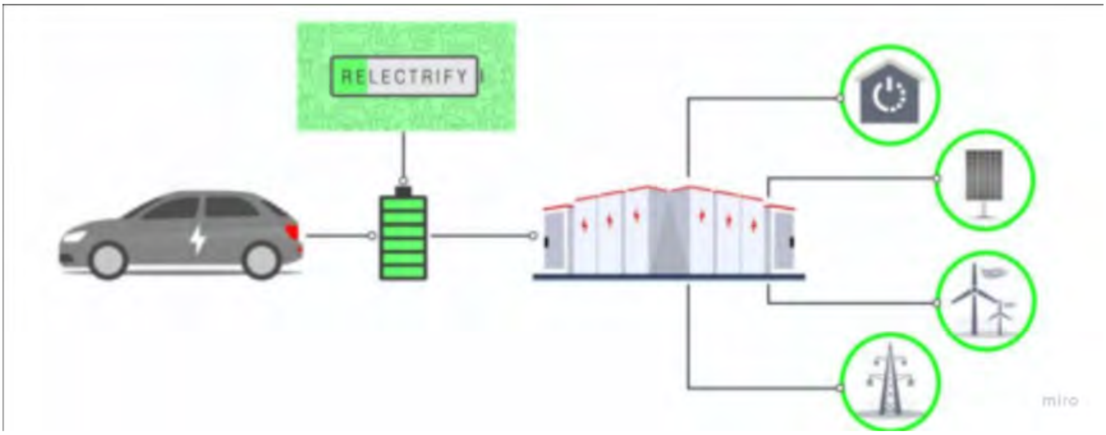


Figure 13. Image taken form Relectrify, 2023 via https://www.relectrify.com/cellswitch

Similarly, Restore is manufacturing first and second-life ESS solutions and has partnered with stakeholders in Norway to create circular economy solutions and mitigate the burden of labor abroad. Restore offers a range of solutions, from household scenarios to large ESS grids and backup systems.

Figure 14. Image taken form Ecostor 2023 via https://www.eco-stor.com/products

There are some interesting cases where home projects have turned into successful start-ups. Smart-power is one such company that creates personalized energy storage systems (ESS) using new or second-hand batteries and provides all the necessary equipment to make them work. One of their first B2U models was installed in a house near Tananger, but the total cost of the installation was around 400,000 NOK (circa 40,000 USD) for a capacity of 32 kWh. This shows that the lack of standardization and high labor fees can limit the use of used EVB applications in small-scale operations, especially when compared to purchasing a new mid-range EV (with a capacity of 70 KWh) for the same budget.

Some municipalities, such as Sola and Lyse, are using repurposed EVB to monitor water pipes, detect possible leaks in the system, and power street lights in off-grid installations. Companies are also exploring the idea of having their grid based on smart charging, where the energy stored in the batteries can be used during peak hours and charged during low peak hours. One example of this is Heldal Eiendom, located outside of Bergen.

ELECTRIC CAR BATTERY: This box contains both measuring devices and a used electric car battery.

PHOTO: OLE ANDREAS BØ / NRK

Figure 15. Image taken by Ole Andreas Bø; 2022 via https://www.nrk.no/rogaland/brukte-elbilbatterier-kan-hindre-flomskader-og-vannlekkasjer-1.15327418

Even companies selling energy solutions based on repurposed EVB, depending on the capacity and power nedded, like Alternativ Energi AS. This solutions come in a simpler way, prefabricated electric compartmets that could be rapid installed.

Alternativ Energi AS

Figure 16. Logo and repurposed batteries pictures taken form Alternativ Energi AS, 2023 via https://www.alternativenergi.no/produkter/batterier/litium-kraftpakke-2448v

Used EVB applications spectrum

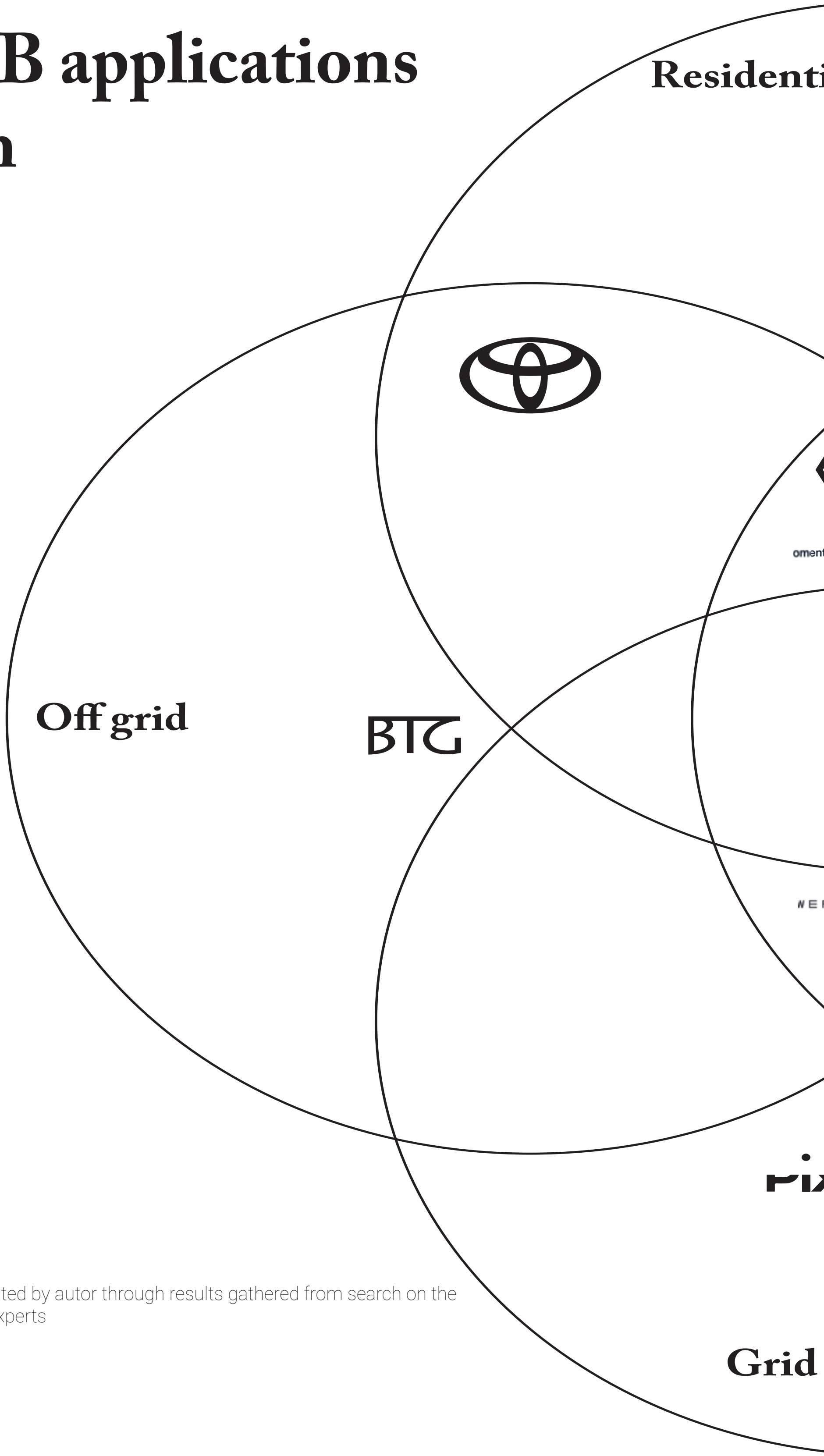
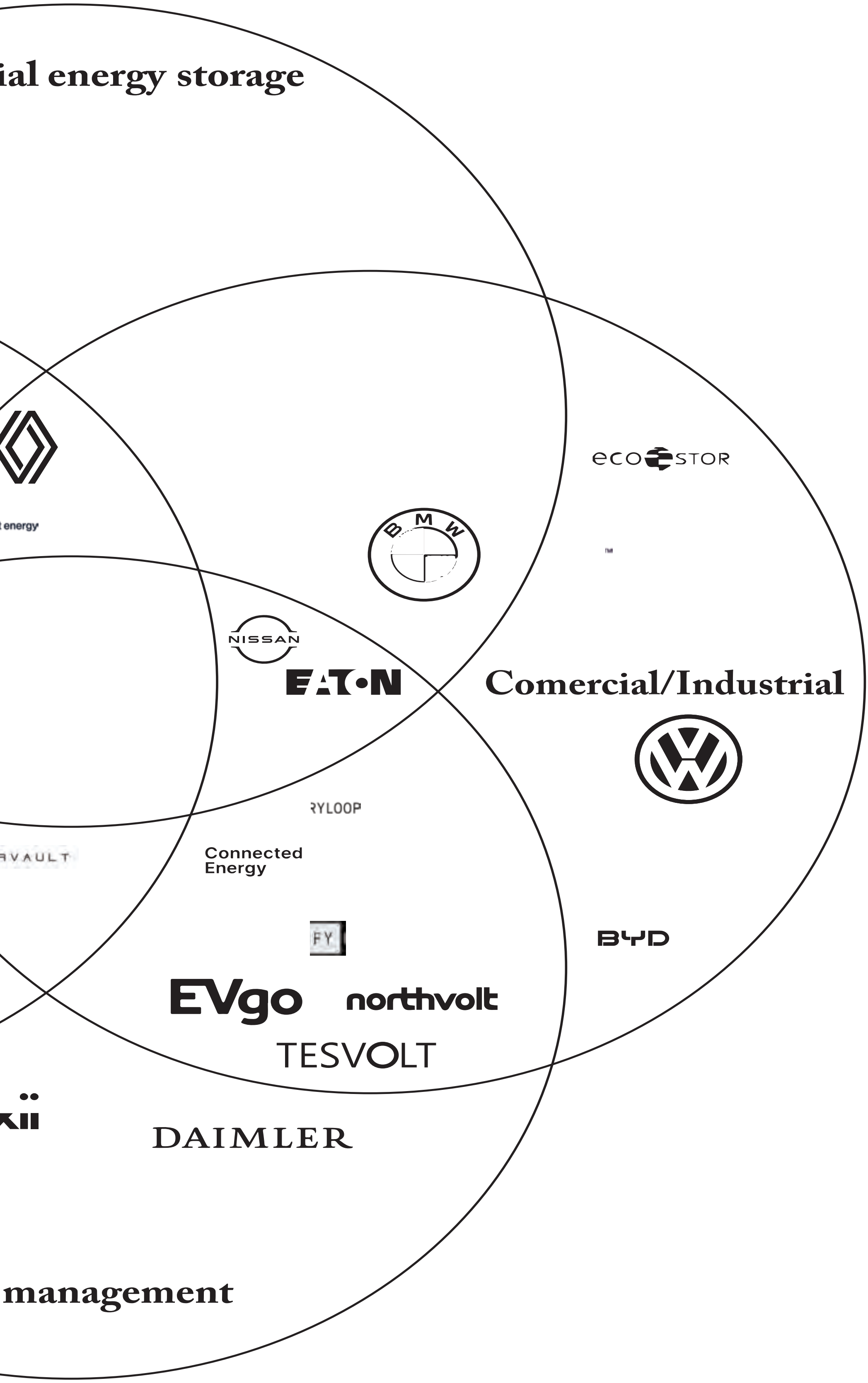


Figure 17. Spectrum map created by autor through results gathered from search on the web and conversations with experts


ial energy storage
Comercial/Industrial
management
ecoSTOR
NISSAN
EATON
Connected Energy
EVgo
northvolt
TESVOLT
BYD
DAIMLER

2. Problem Statement

Battery packs for electric vehicles come in different sizes, electrode chemistry, and formats, and this diversity is expected to grow as more than 15 manufacturers are set to introduce up to 250 new EV models by 2025. Refurbishing these batteries can be a complex process due to the lack of standardization, as each battery is designed for specific EV models and has its lifespan depending on its design, production, and user behavior during the first life stage.

To address the lack of standardization in terms of quality, safety, and performance, manufacturers, recycling and refurbishment companies, and second-life battery companies must work together to establish standards that classify the performance potential of batteries for different activities and how they behave with the help of BMS. This will provide transparency in product supply and market demand. Creating a body to regularly review and refine battery standards and provide feedback on usability behavior, such as a battery passport, can also be helpful.

Current regulations do not determine whether recycling or reuse is the best option for an EV battery, leading to regional differences in recycling and reuse rates and uncertainty for OEMs, second-life battery companies, and potential customers. To address this issue, stakeholders should proactively identify the most appropriate path for value maximization, whether through recycling or reuse and develop new business models to capture the value at hand fully.

As new lithium-ion battery costs continue to fall, firms must industrialize and scale remanufacturing processes to reduce costs and maintain the value gap between new and used batteries. Establishing connections and cooperation between stakeholders is also crucial in this immature market, as it can help gain early recognition from future users over possible repurposes and how they can help achieve sustainability goals.

Project Scope

This project aims to investigate the possibilities of creating a product that utilizes scalable and versatile repurposing solutions for used electric vehicle batteries. This product should be adaptable to various scenarios and contexts.

3. Methodology

For this thesis, speculative design was chosen as the methodology based on insights and results gathered from pre-research. Careful planning and information gathering from past research and stakeholders in the EVB life cycle led to proposed scenarios for future users. However, extensive data collection was required due to uncertainty and limited information on repurposing applications for B2U from some companies. The data collection phase proved to be the most extensive part of the process, and some setbacks occurred, requiring new analysis to reach the ideal scenario.

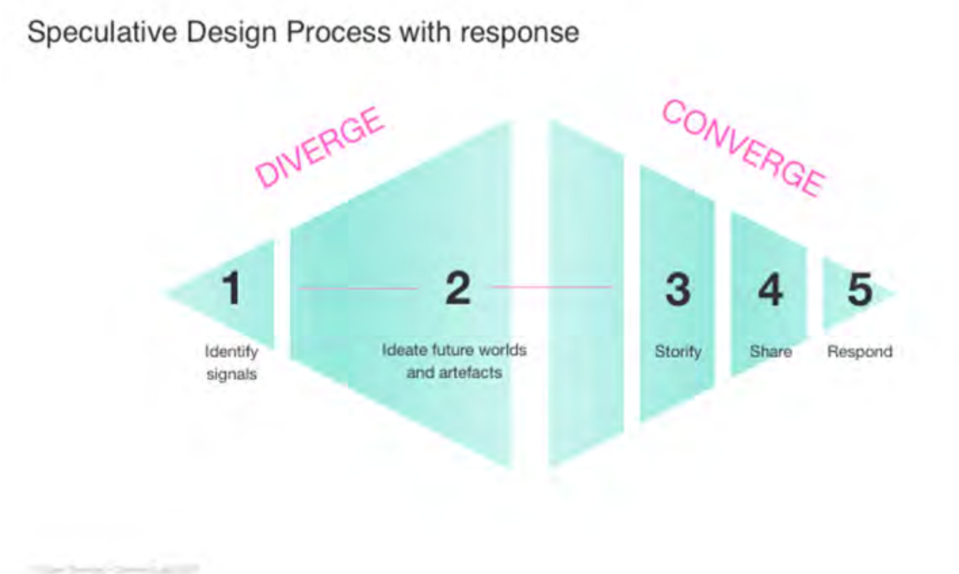


Figure 18. Method graphic created by Damien Lutz, 2023 taken via https://uxdesign.cc/future-thieving-2-speculative-design-methods-tools-45b655096d95

Initial design brief

A design brief was emailed to companies involved in the EVB life cycle. The brief outlines the project's direction, my perspective from early scenarios, and feedback gathered from potential users during workshops. The brief also presented three developed scenarios for repurposed EVBs and sought feedback from stakeholders on their thoughts regarding the scenarios and observations from future users.

Previous scenarios and future users' feedback

As part of the project, I developed concepts for household ESS applications, focusing on the market perspective. The first scenario involved the car industry taking responsibility for inactivating the EV user's old battery and transforming it into a battery pack for their homes. This value proposition would be included with the car purchase. The second scenario proposed battery modules that could be sold individually or in specialized electronics stores. These modules would be stackable, allowing users to build their own battery pack based on their needs and budget. The last scenario involved a household application that allowed users to remove some modules and use them as a mobile battery or power bank.

Scenario 1

When purchasing a car from a specific manufacturer, users are provided with the opportunity to repurpose the battery within their own households. This is part of the manufacturer's commitment to circular economy and battery lifecycle, as it helps to reduce grid usage and promote responsible electricity consumption.

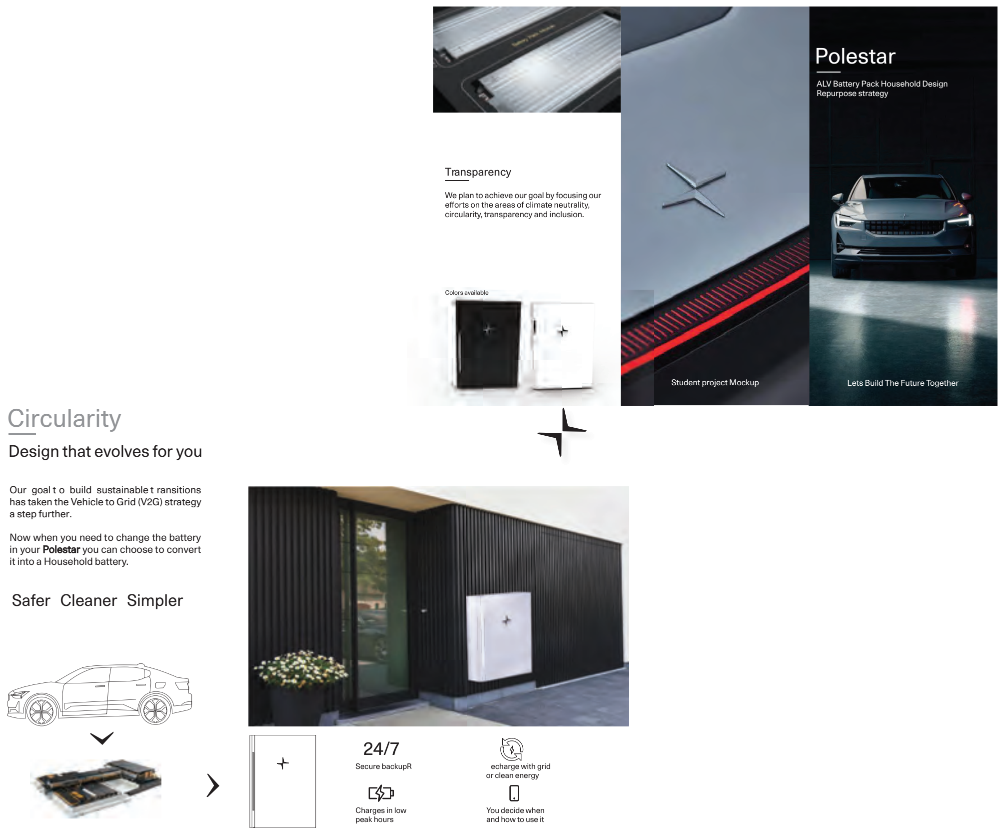


Figure 19. Brochure made by author with Polestar graphic profile

Scenario 2

A company specializing in remanufacturing offers used battery modules to individuals who do not require or cannot afford an entire battery pack. These modules can be purchased and transported as needed or connected to a grid for charging. The modular design allows for the flexibility of stacking as many modules as necessary to create a custom battery pack that suits one's needs and financial resources.

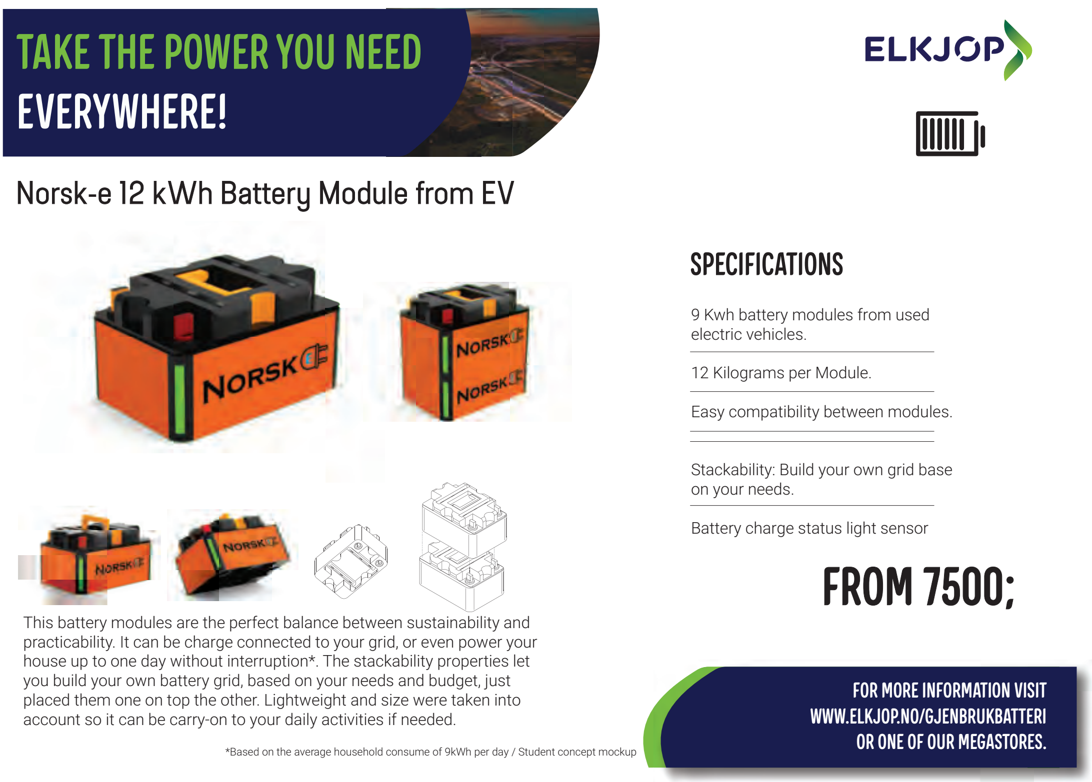


Figure 20.. Brochure made by author with Elkjøp graphic profile

Scenario 3

A company specializing in remanufacturing offers used battery modules to individuals who do not require or cannot afford an entire battery pack. These modules can be purchased and transported as needed or connected to a grid for charging. The modular design allows for the flexibility of stacking as many modules as necessary to create a custom battery pack that suits one's needs and financial resources.

Figure 21. Brochure made by author with Hyttetorget graphic profile

Future users feedback

Through the creation of user personas, modularity is found to be intriguing as it offers the potential to fill various niches in the market. This approach also allows for versatile second-life uses for EV batteries, utilizing the same product or application for different needs.

During discussions, various factors such as pricing, capacity, warranty, responsibility, maintenance, previous battery usage, benefits, and safety have emerged as important variables to consider when developing the final concept.

Scenario 3

Information that should be add	possible changes	User group / Use areas
Price / capacity of the modules	Should be able to combine the backpack with other wearable gear	Family that has a cabin that can be used the whole year
Warranty/ who installs it	Should show use's examples for the backpack	Watering a garden Grass mower battery for E-bike Electric kitcken
Battery history / safety aspects	Indicator to show when small modules are low of charge	People that lives and work in remote areas that might need energy from mobile sources

Personas for each Scenario Concept

Who could be the possible user group for this scenarios

S1 - Samantha Giske 42yrs.

Employee. Head of a family of 4, would like to save money in energy, mostly on winter when it gets so expensive.

Would consider adding a battery to her household that would helper to alleviate the energy consumption and cost.

S2 - Erika Leclerc 35yrs.

Self employ, needs to travel a lot while working and needs a generator for the tools that she uses at work.

Would like to have some greener power source that could provide energy to the tools she uses and that would be lighter and more transportable.

S3 - Mike Petersen 28 yrs.

Likes to go to his cabin every time he can, in every season. He has a lot of season projects to work on to have the cabin ready for the next one. He doesn't like to use a fuel generator as it is not sustainable but the battery he has in the cabin isn't powerful enough to charge his tools and keep the cabin light up.

Stakeholders map in Norway

Production

Raw materials

Recycling

First use

Recollection

STENA RECYCLING
Li-Cycle
NORSIRK
BatteriRetur

Refurbishment

BATTERYLOOP
REPURPOSE ENERGY

Second life

ecoSTOR
BATTERYLOOP
northvolt

Figure 22.. Map produced by Autor based on web research and stakeholders feedback

Stakeholders

I contacted various stakeholders involved in the EVB life cycle to present the preliminary design brief, previously created scenarios, and feedback from future users. I aimed to gather their position on second-use batteries, their opinions regarding the concepts developed in the pre-investigation phase, and generate possible insights about it. I reached out to around 40 companies that are part of the EVB life cycle in Norway and internationally. Out of those, 12 experts responded, but only five were available during the process. Several of these experts worked with other companies that are part of the EVB life cycle but at different stages.

I had conversations with companies in different life cycle stages, both in Norway and Latin America. These conversations occurred through events, group meetings, and unstructured interviews via email or video call. We contacted Company A, Company B, and Company C in the area of battery production, and Company D and Company E dedicated to collection and recycling, in addition to being facilitators in the entire legal process. Company D gave us information about the Company F subsidiary about remanufacturing processes.

Figure 23. Batteri Retur showing some EV battery pack in automesen 2022, picture taken from Batteri Retur Linkeling profile via https://www.linkedin.com/company/batteriretur/

Stakeholders provided their thoughts on the usage of EVB applications, expressed their concerns about different scenarios, and gave feedback on the presented concepts.

Stakeholders Insights

- According to Companies A and C, batteries are lasting longer than expected, which could allow for more time to optimize repurposing and recycling processes.

- Companies A, B, and D stated that the second life of batteries depends on their first life activity. SOH is used to determine whether it is optimal to refurbish modules, but the lack of standardization slows down the whole process.

- Company A revealed that battery modules or cells could be combined with different battery modules if they have the same chemical composition. Ideally, they should be combined with modules from the same production batch, formation processes, manufacturing type, and BMS.

- Company E suggested that dangers during the diagnostic process can be avoided by discharging the batteries, but the energy could be stored or used for other purposes.
- Company B emphasized that automation is necessary for the remanufacturing and refurbishing process to lower prices and make it more attractive in the market than new batteries. Otherwise, the B2U applications could have an economy off-scale effect.

- Experts from Company D and F stated that it is not worth reusing batteries as materials optimization could create four new batteries with the same materials as the old one, creating uncertainty in the cycle.

- Partnerships among stakeholders are crucial to achieving optimal results and products that can alleviate the environmental burden from the production phase. This is exemplified by Company B's partnership with Company E, a battery producer, and first and second-life battery company in Norway, aiming to generate repurposed solutions and their circular economy. Meanwhile, Company D has partnerships with another recycling company and battery remanufacturer.

- Companies A, C, and D claimed that user behavior needs to change as the second life of the batteries depends strictly on their first usage.

- A battery passport should be generated even for repurposed batteries so that the user knows the exact conditions of the battery and can calculate the subsequent life span.

- The second-life applications could address or decrease various environmental fees.

- Company D's expert highlighted that one of the challenges would be having enough capacity to obtain raw materials, as there would not be enough with the production boom, which could prevent reaching circularity in the EVB life cycle.

- According to Company D, EV batteries should have some percentage of the material mass collected to be recycled, and the batteries should remain in the country.

- Concerns regarding how to convince people to choose used batteries over new, who is responsible for the batteries after they are placed in the second life, and regulations were raised by Companies D and C.

Stakeholders concepts' feedback

- The key aspects of each concept could be combined in a more practical way, specifically in regards to the scenario involving a backpack for plugging in devices. This would include branding, modularity, and potential mobility (though the latter requires further development and certifications).

- While batteries already have a BMS, it would be beneficial to incorporate an additional system that can provide information to the user and allow for interaction.

- Possible user needs?

- In what ways can we make the B2U app appealing to users and encourage them to choose it over a newer alternative?

- It is advisable to showcase the versatility of concepts by visualizing them in various contexts.

- Let's consider the scenario of a yearly subscription or leasing, which are both economic models.

- Battery connections to the grid and/or energy source

Identifying signals of emerging technologies and trends

Research about various second-life EVB scenarios was conducted and gathered insights from sources like Mckinsey Technologies, Volue (Spark), and DNV, which provided forecasts for energy transition trends aimed at achieving the 2030 sustainability goals for the EV ecosystem and EVB life cycle.

Figure 24. Word cloud created by Auto after gathering data from web search.

Future product ideation

In light of the rapid growth and innovation in the automotive and EVB industries, future product ideation should prioritize evaluating terms, variables, threats, and emerging technologies that can be adapted to the market to build a sustainable path toward achieving circular economy goals. One of the main concerns that can be turned into opportunities is the uncertainty among stakeholders on how to handle batteries after their first life, as well as issues surrounding battery standardization, consumer acceptance, market conditions, and safety. According to trends and previous research, energy storage systems, particularly for household applications, are the most studied and promising area to work with, with the potential for adaptation to other contexts.

Figure 25. Image generated by AI with keywords future and mobility – Open source

Scenario forecast

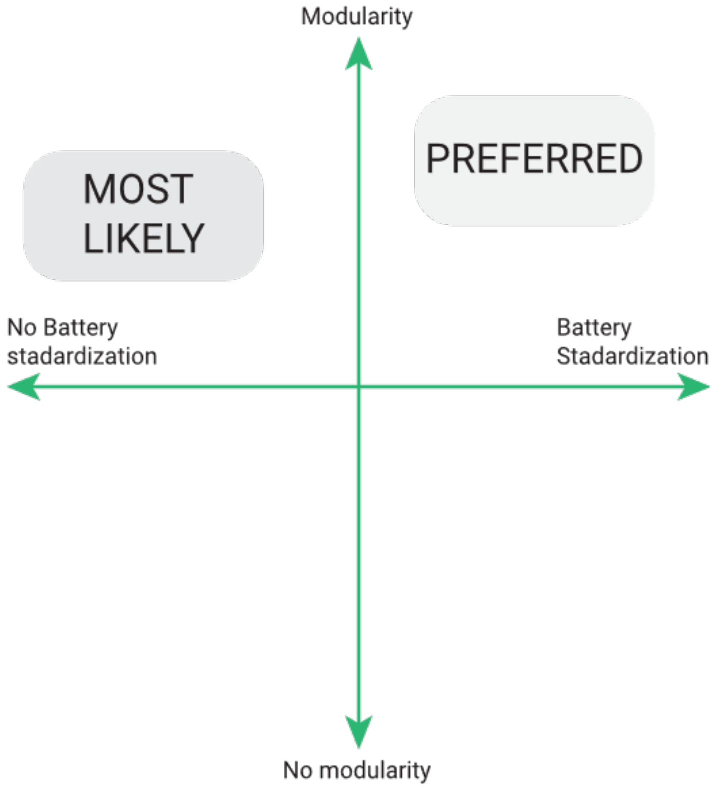


Figure 25. Forecaste graph created by author.

Experts and web search results have highlighted a potential threat, which has created various future scenarios. Additionally, EVB production experts have identified a unique value proposition in second-life batteries. Standardization and modularity have emerged as critical factors to consider in these future scenarios, particularly in the value chain for used EVBs. As a result, they have been used as categories for different future scenarios.

The most desirable scenario would be one where battery modules and packs are standardized, making them more accessible for future users. Modularity is crucial, allowing second-life batteries to adapt to different situations and scenarios while remaining versatile, available, and affordable.

Scenario 1

There are two standardized types of batteries which have made the life cycle easier. Companies that specialize in the remanufacturing and recycling of batteries can focus on one type, making the process more efficient and optimizing the recovered parts for use in second-use applications. This standardization of battery modules promotes transparency among automotive brands, all working towards a common goal of circular economy.

The cost of battery modules has dropped due to process optimization and low labor costs, making them an attractive option for those who wish to reduce energy costs in their homes, create their own off-grid power source, or have access to power in remote areas.

However, the lack of standardization and the possibility of more battery types in the future, each unique to a particular automotive brand, means that it would be ideal for second-use batteries to be modular without standardization. This would require the market niche or all applications to adapt and innovate to suit this scenario.

Scenario 2

Automotive brands continue to focus on the value proposition of different types of batteries, leading to a growing gap between them. However, various remanufacturing methods have been adapted to cater to the treatment of different types of batteries. This allows users to choose the type of battery they require for their second-life application based on its chemistry and usage history in powertrains.

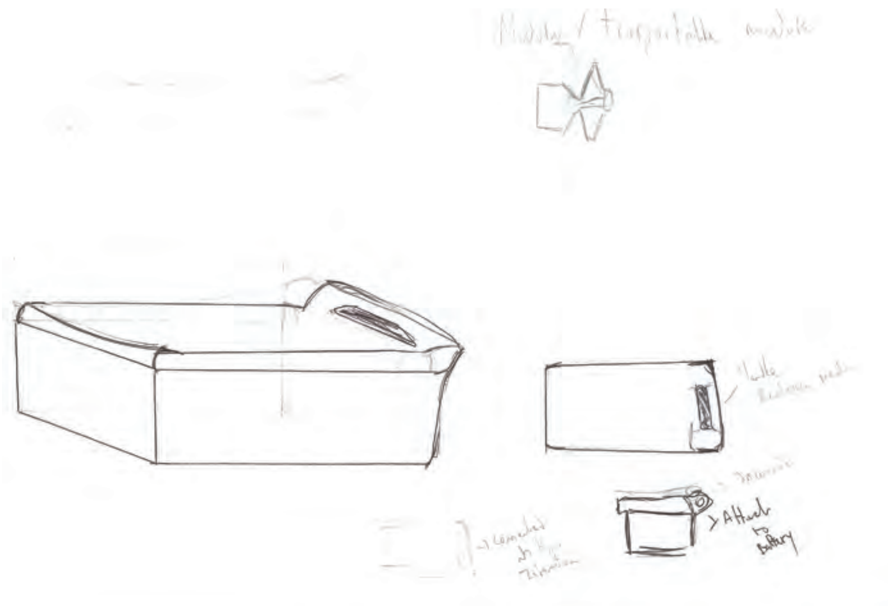
Additionally, the modules' capacity and size have been adjusted to enable users to determine how many they need based on their consumption and budget. This modularity supports more users in purchasing Energy Storage Systems (ESS) to save energy and money during the energy transition process. It also allows for specific maintenance to be carried out on each module individually without interrupting the entire system's operation. Moreover, this modularity enables the B2U application to be adapted or scaled as necessary over time.

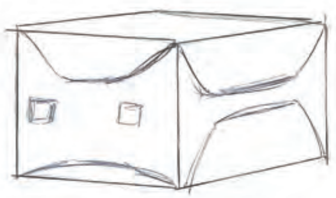
Concept visions based on variables to consider

These conceptual visions were developed by gathering keywords from online search insights, conducting interviews with experts, and discussing with my supervisors. Each variable represents different approaches to the product that underwent several iterations.

Accesibility

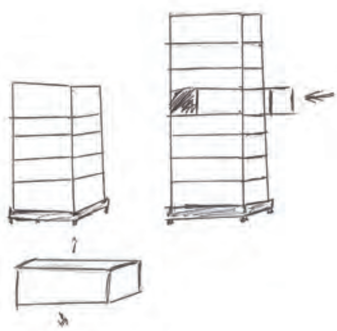
Access to energy should be available in any location, including areas with limited infrastructure or connectivity. It's essential to have both a digital and physical interface available for users in case remote communication is impossible.





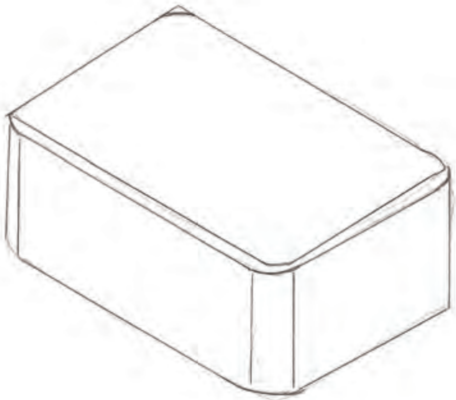
Scalability

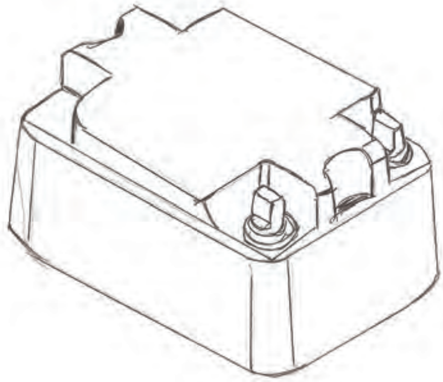
The Energy Storage System (ESS) should be able to seamlessly integrate with the grid and other renewable energy sources such as solar, wind, or district heating. This means that it can assist in balancing the load on the grid, share energy through it, or even serve as a new energy source in off-grid areas.

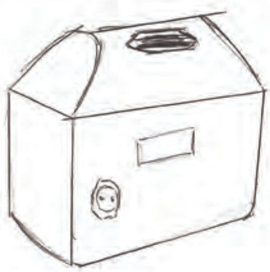


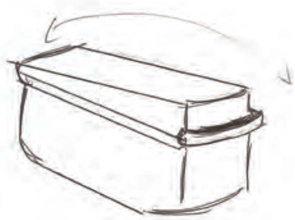
Modularity

To provide flexibility in terms of budget and necessity, modularity must be a significant aspect of the ESS for users to build it up. This implies that they can begin with either two modules or a complete scaled battery pack, with the option of adding more modules as required later on.



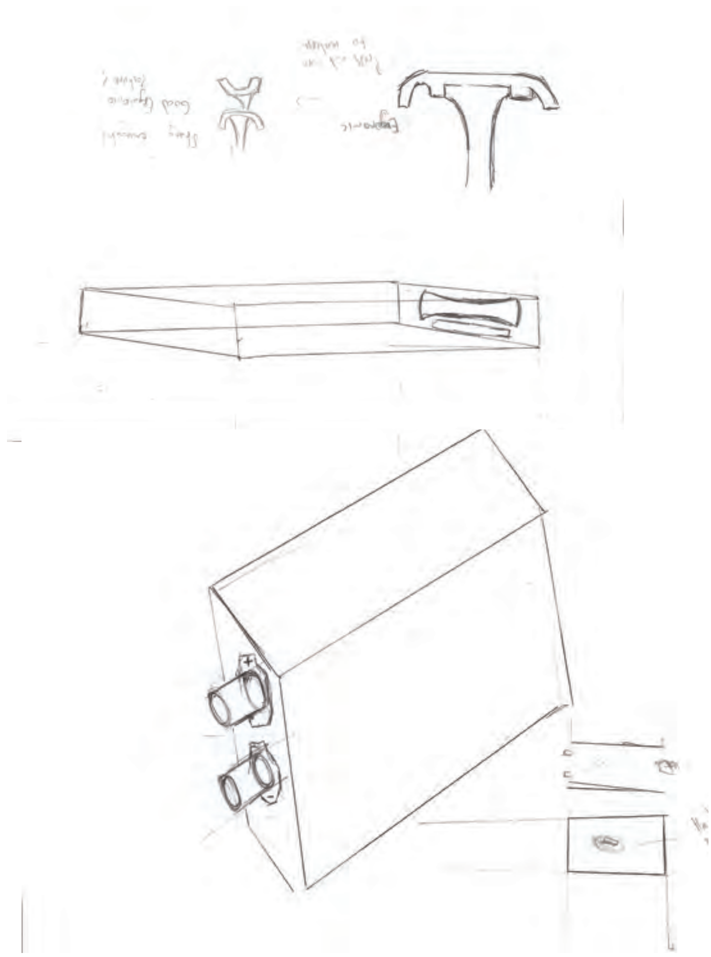






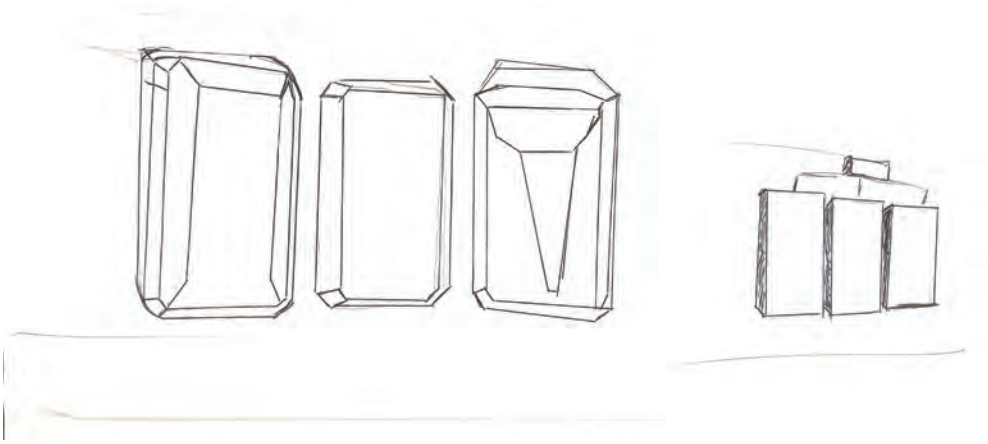
Suitable

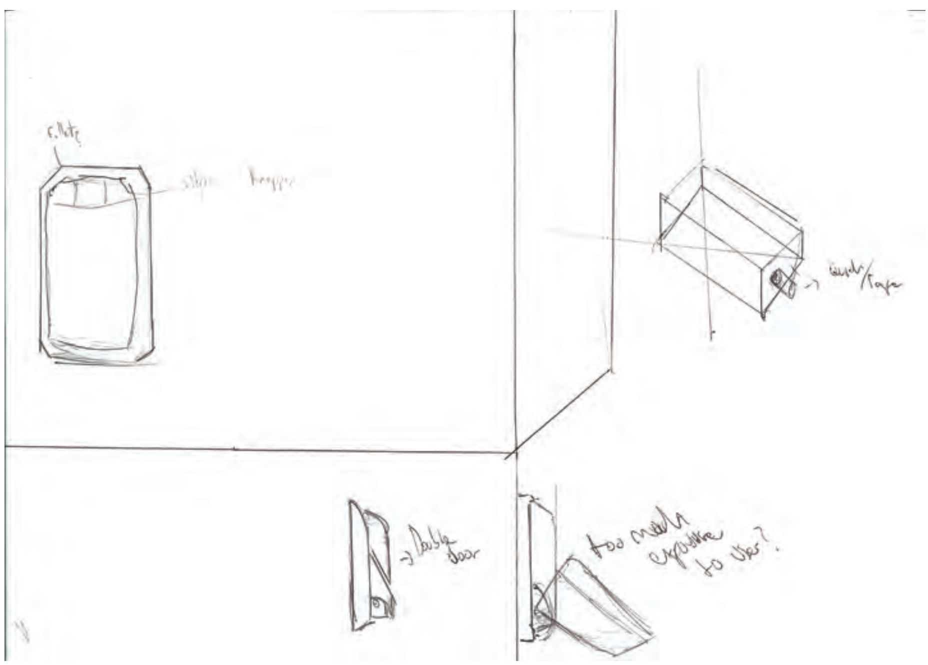
A significant concern is the variety of batteries available in the market, which can slow down the refurbishing process. Although it is possible to create packs with different module types, they may have different connector types, which can be challenging. A universal connector or converter can be integrated into any module to simplify the adaptation process and make remanufacturing easier. This will relieve some of the steps involved in the process.



Adaptability/expandability

The application for second-life batteries should be adaptable to various contexts and cater to the user's needs while considering the space and location.

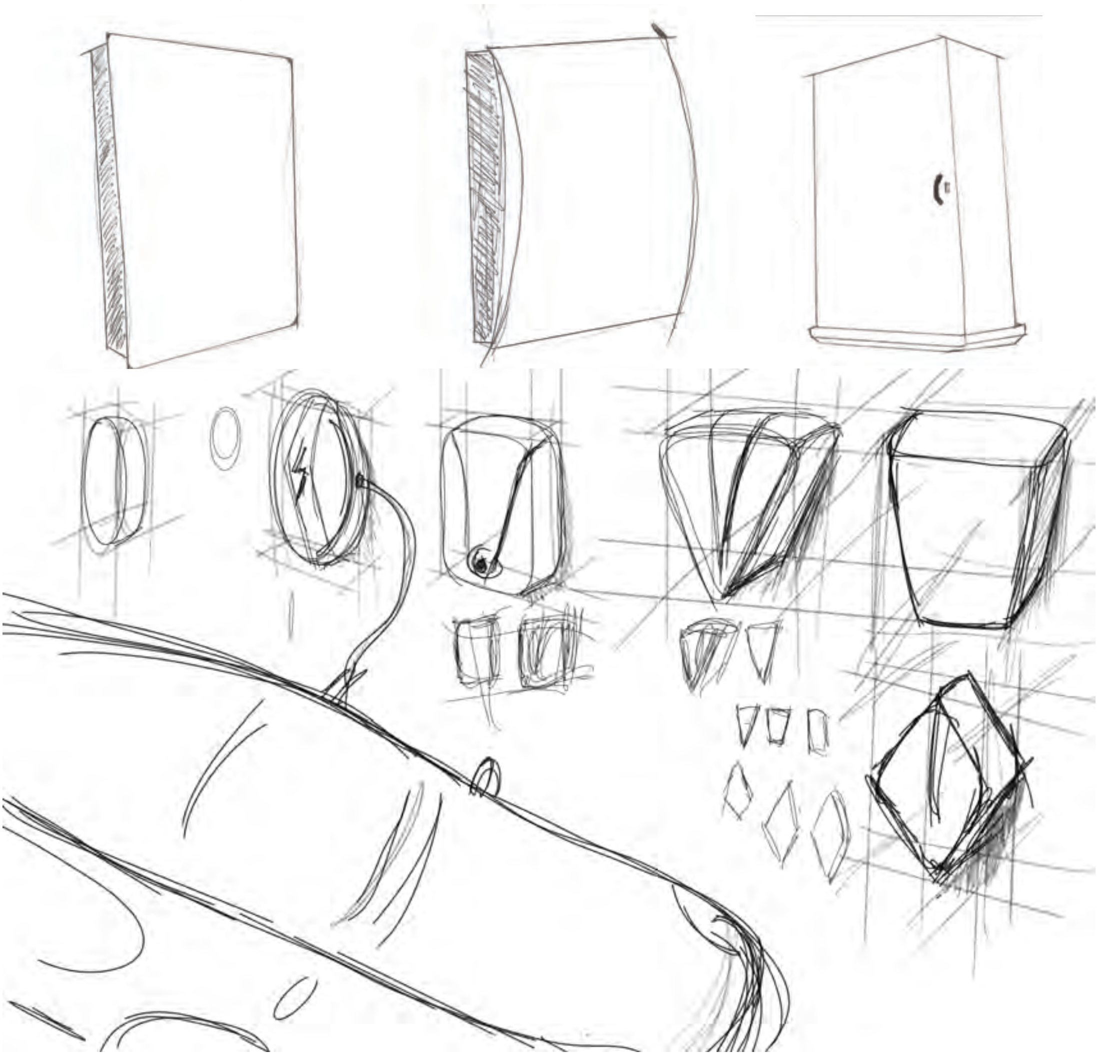




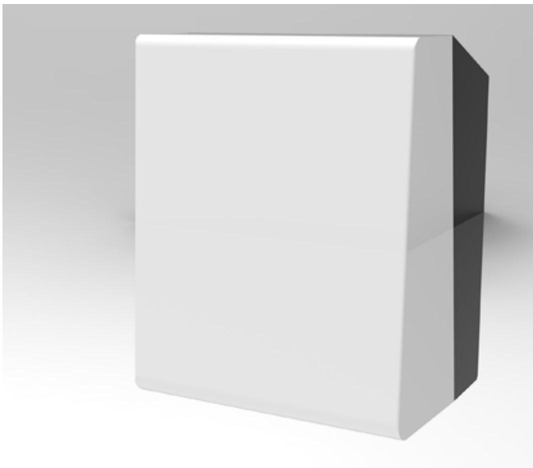
Ideate future product

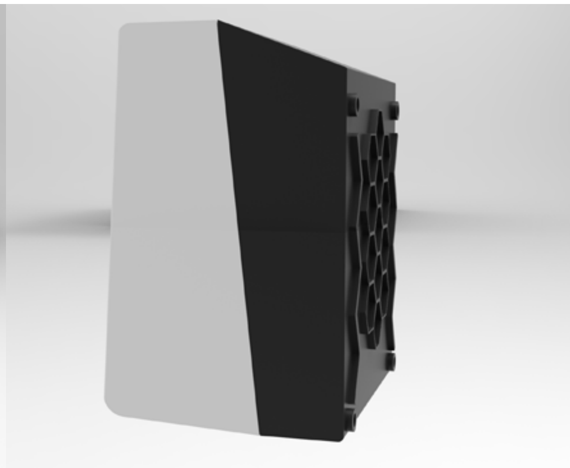
After considering various variables and insights gathered from web research, and feedback from experts and supervisors, we have established a timeframe of 2030, which aligns with the sustainability goals of the United Nations and the European Union.

I began visualizing the integration of a battery into a house, keeping both productivity and aesthetics in mind. From there, I explored how this technology could be applied to other objects, such as vehicle chargers, considering every aspect, including attachment to surfaces and user interaction.

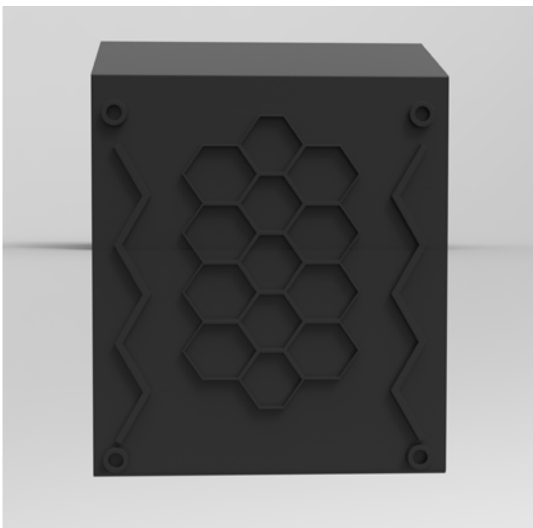


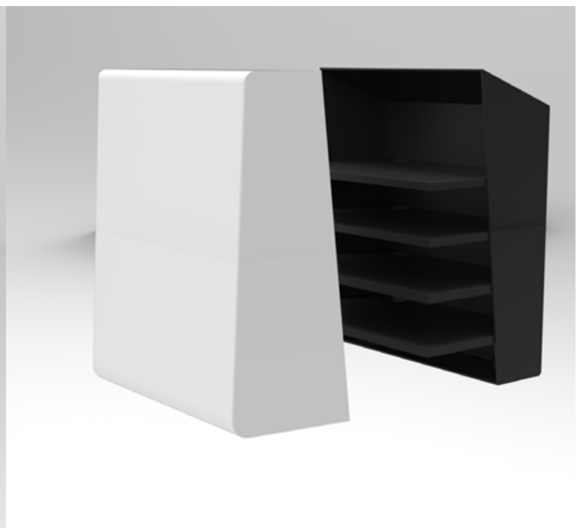
Sketching and quick modeling was used to put those parameters or variables in a product spectrum.





Exploring parameters like internal modularity and context integration.

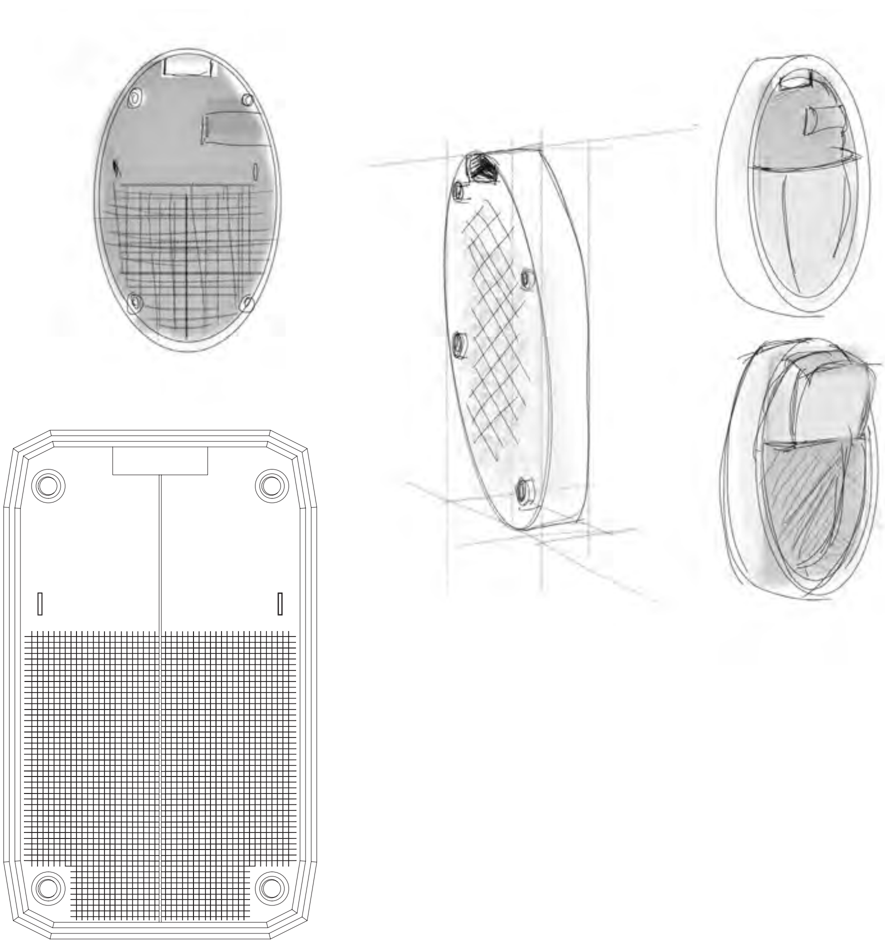


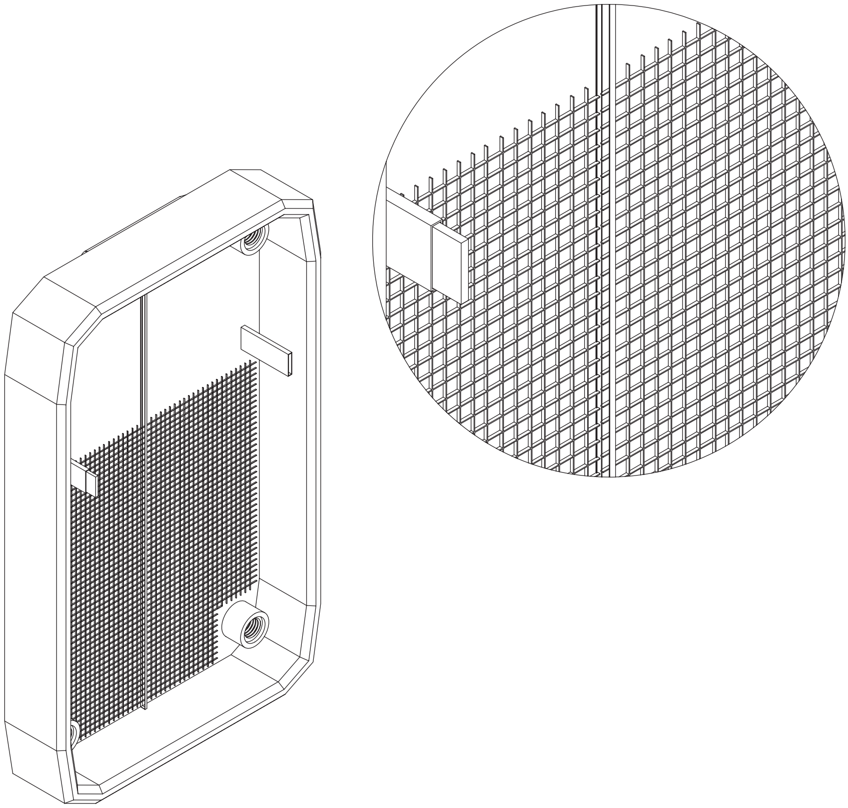


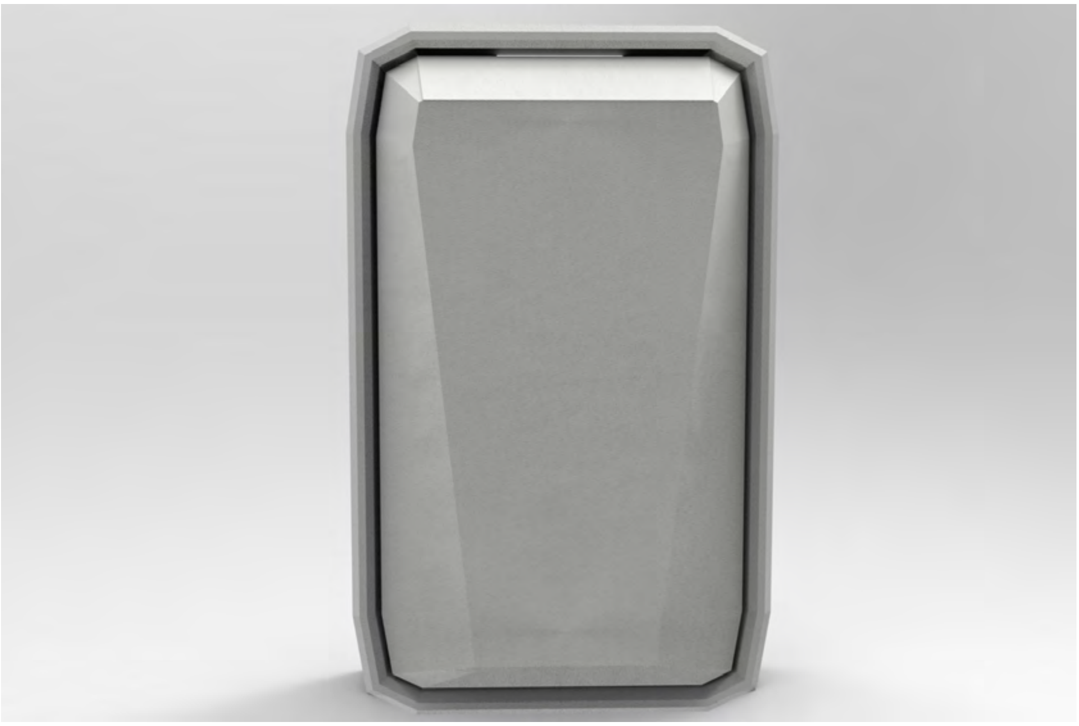
A MoSCoW mapping was conducted to determine the key factors of the concept and prioritize them after analyzing various applications.

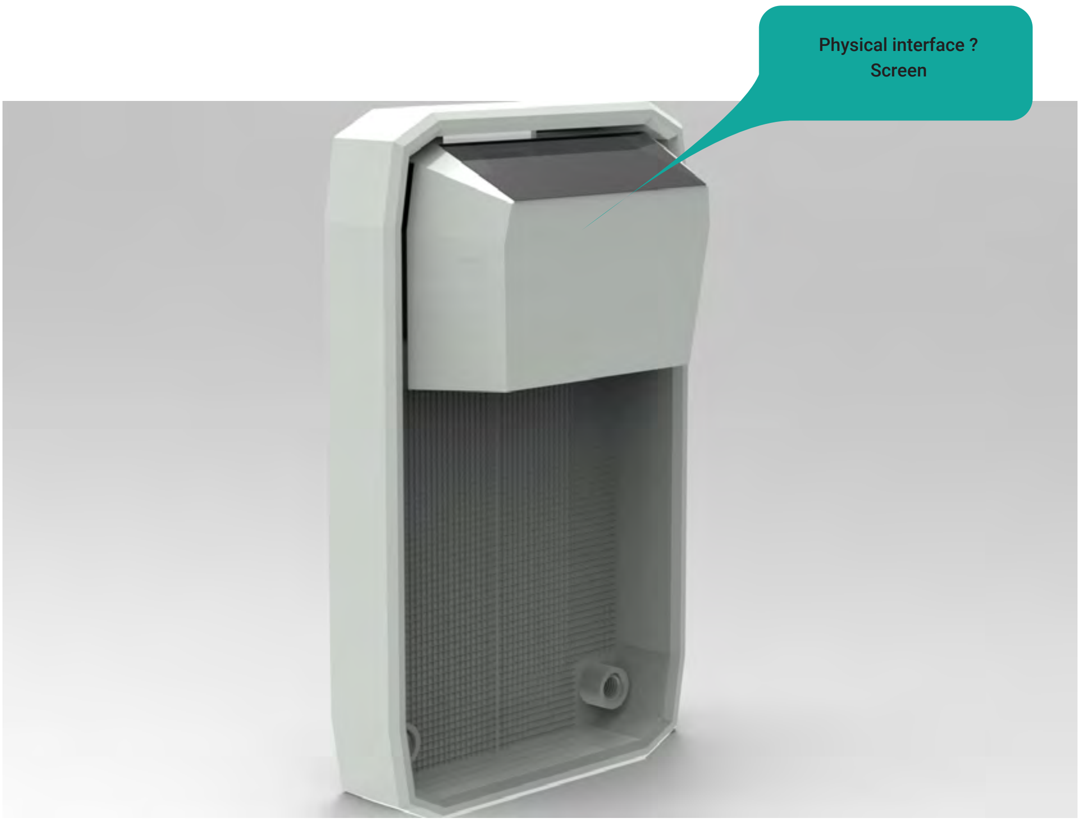
Modularity has been the most attractive and relevant aspect throughout the process, as it allows for thousands of proposals to be devised. Let's take a closer look at the remanufacturing process. Firstly, the products must be dismantled and checked to determine their state of health. This stage provides three options: creating new modules with the battery cells to meet the users' needs, recycling the cells if their condition is poor, or using these modules in already planned applications.

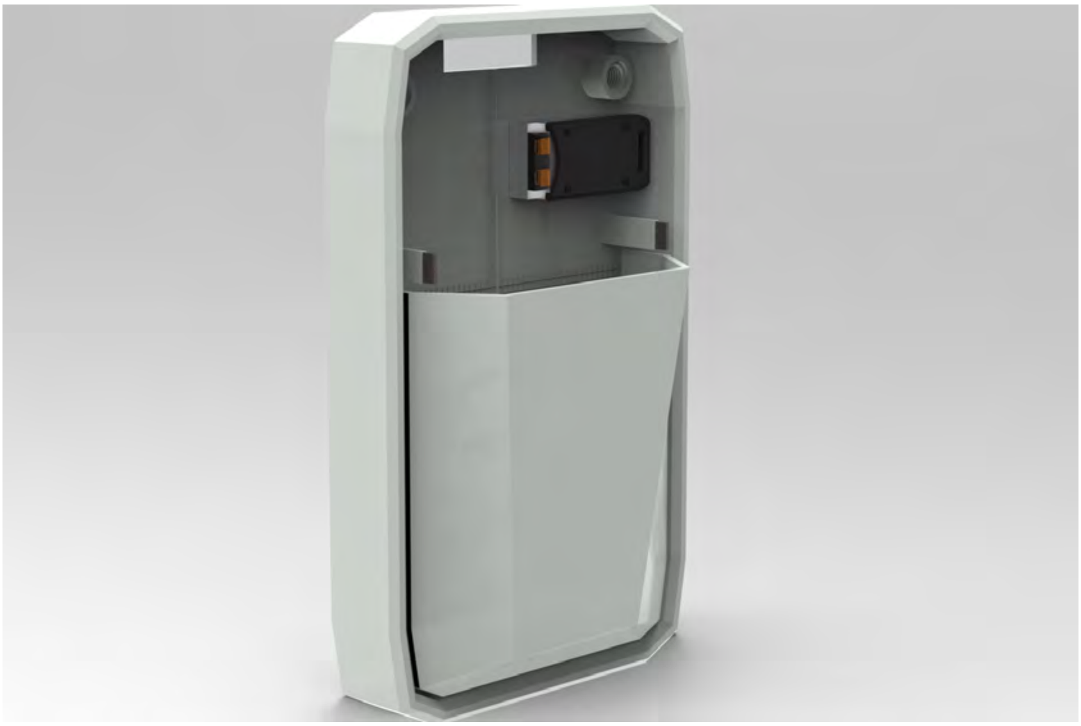
What if we could generate a disruptive modulation scheme that allows any module to be adapted to a type of mesh or reticle, considering the manufacturer's restrictions? This might help save processes and materials during the refurbishment stage.

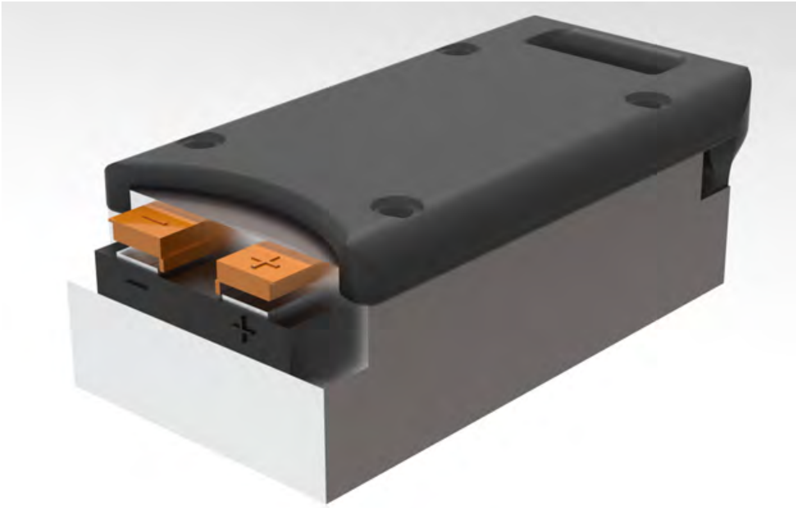


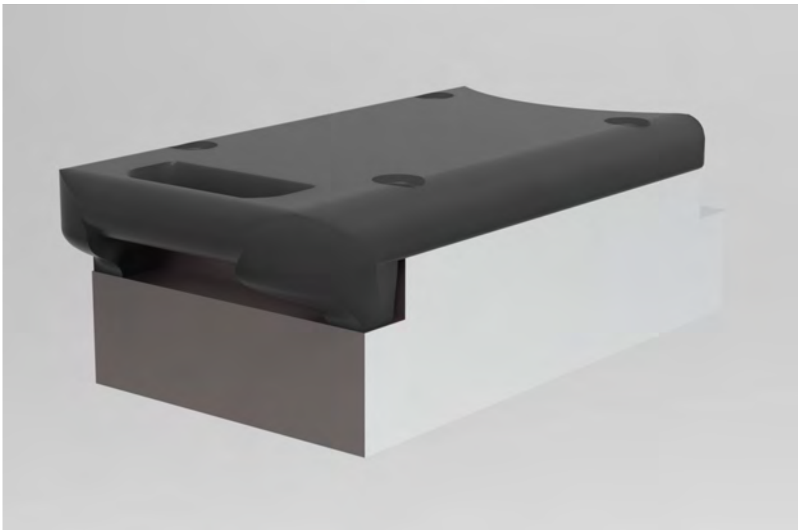


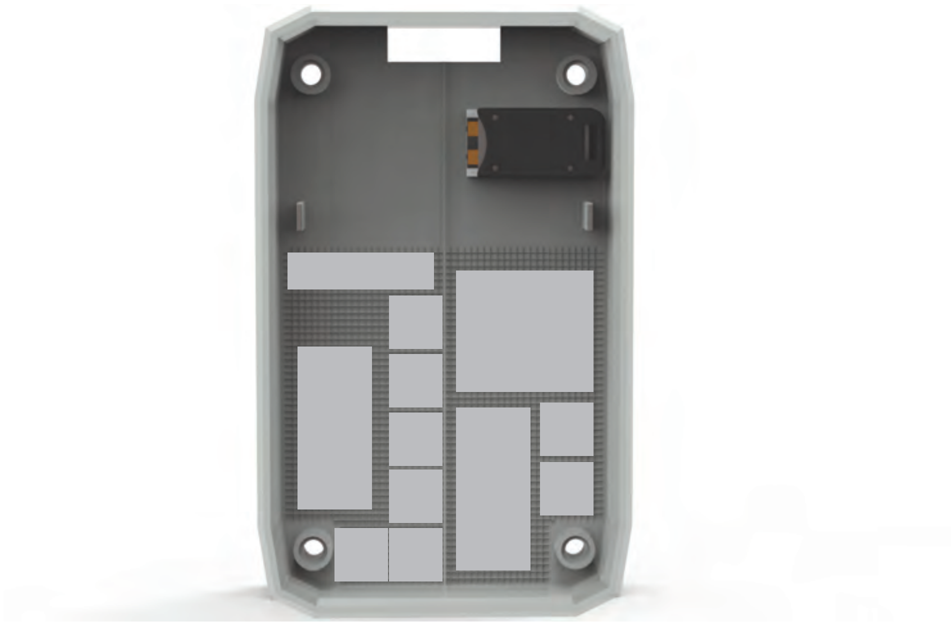



Physical interface ?
Screen



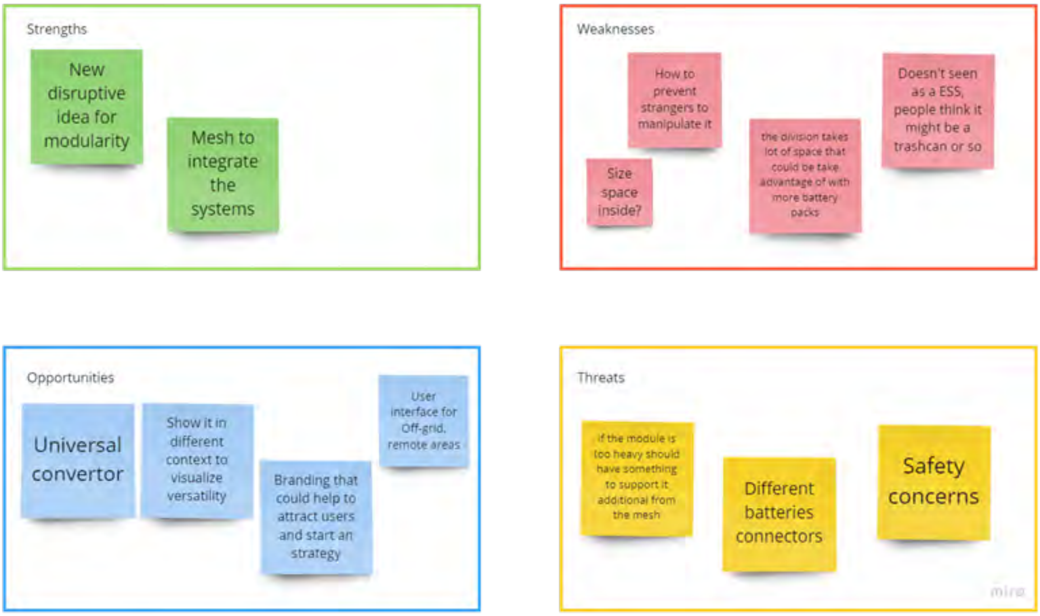






Battery modules concepts and how variations of them could attach or adapt into the mesh inside the ESS comparment.

During the used EVB life cycle future ideation, we presented the concept of adaptable modularity to two companies. They were intrigued by the potential of this concept to save time and resources in the remanufacturing process while providing users with the flexibility to choose the modularity that suits their needs. However, they would like to see another iteration of the modulation to ensure compatibility with different sizes of battery modules.
Additionally, they are curious about how the battery modules would be connected to the mesh. They suggested that the mesh or reticle could be used for more than just connecting battery modules, such as organizing wiring or adding attachments.
Lastly, both experts and supervisors recommended putting the product in context and associating it with a well-known brand or logo to generate more credibility and attract potential users. One expert also pointed out that there is potential to increase the number of battery modules by optimizing the use of space in the division between static and transportable modules.



Based on the feedback gathered from future product ideation, a SWOT matrix was created to determine the final path for the last product iteration.

4. Final product ideation.

NORSK-E

After receiving feedback and insights from experts and supervisors, the final concept was developed using three main components: the brand, the shell or compartment, and versatile modulation. These bases were carefully chosen to ensure the best possible outcome looking to adapt it into the green energy transition.

Brand

During a previous investigation, creating a brand was developed to showcase how different markets could sell EBV applications. The goal was to establish a communication strategy that people could relate to and create an identity for EBV applications. As a result, two concepts were made under the name Norsk-E (with E standing for energy) to establish a strong image of the energy transition in Norway.

The first concept used a logo that combined typography and a power adapter icon, with white, black, and turquoise colors commonly used in logos to differentiate electric vehicles from traditional ones. This concept aimed to visualize a brand dedicated to energy solutions.

After receiving expert feedback, I developed a brand concept for companies dealing with the EVB life cycle to showcase their products and gain a foothold in the market. This concept could also showcase partnerships and cooperation between companies, giving users an image of reliability and transparency to accelerate the adoption of innovative energy storage solutions. The second concept used the same name, but the logo included the common denominator, the battery, with a change in the color palette to black, white, and green.

The development of a graphic profile could help to deliver infromation and make future users familiarize with the brand and products.

R: 17 G: 17 B: 17 | R: 255 G: 255 B: 255 | R: 54 G: 116 B: 96

NORSK-E

NORSK-E

The NORSKE logo incorporates sleek, dynamic lines symbolizing energy flow on the batteries, while vibrant green hues evoke sustainability and growth. This visual representation serves as a reminder that electric vehicle batteries can continue to power a sustainable future even after their primary use.

Initially, the brand should be introduced to gain users' trust and be recognized later when the products enter the market, gaining coverage for future users. This could introduce other types of strategies that redefine how we use energy, seeking awareness of responsible energy use, changing user behavior in the first life of vehicles, increasing the possibility of battery remanufacturing, and attracting future users to products that use second-use batteries as the market matures—possibly increasing energy sharing between communities.


NORSK-E


NORSK-E

Brand storytelling

Norske's purpose is to promote sustainability and lessen our impact on the environment. We understand the potential of used electric vehicle batteries and are devoted to transforming them into unique energy storage solutions. Our exceptional technology and dedication to environmental responsibility allow us to tap into unused energy and encourage individuals to embrace sustainable practices. By prolonging the lifespan of these batteries, we intend to decrease the pressure on natural resources and contribute to a more eco-friendly future.

NORSK-E

Energizing Sustainability with Used Electric Vehicle Batteries.

Compartment/Shell

The shell evolved around the feedback received on the previous version. The final concept features aspects such as a physical interface to enable management in remote areas, user recognition via NFC as with smart home chargers. The mesh integrated into the compartment occupies 89% of the total internal area of the case, optimizing the interior space so that more battery modules can be attached, using the same concept for the organization of wiring and other components.

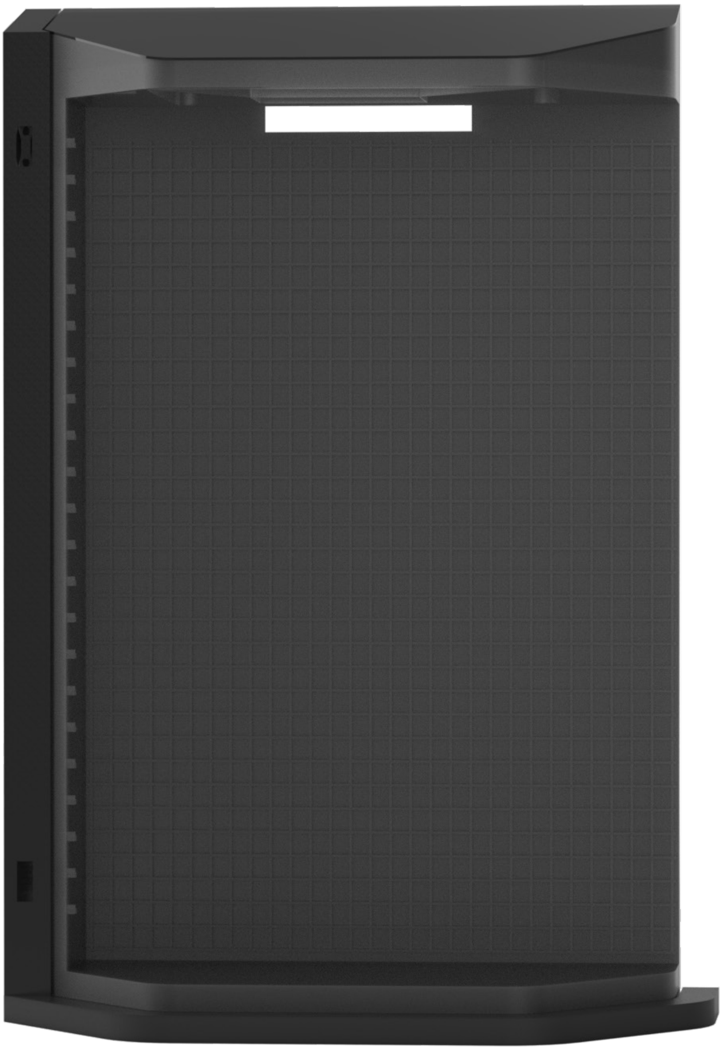
This concept is seen as a blank opportunity or as a blueprint for the user to build their own battery pack, also allowing to add modules when necessary and the casing has the possibility of connecting with 5 more, allowing its capacity to be increased in parallel with the user's energy usage.


Status
Sharing to the Grid
Battery
75%
Options
NORSK-E

A physical interface was integrated to facilitate adaptation to remote contexts, 90 degree opening of the compartment to facilitate access and manipulation of the internal part of the casing.


Status
Sharing to the Grid
Options
Battery
75%
NORSK-E


Status
Sharing to the Grid
Battery
75%
Options
NORSK-E



In addition to the mesh to integrate the internal components, levels were generated on the left side of the structure to install supports if necessary due to the weight of the battery modules, thus seeking to distribute the weight and not generate loads that endanger the integrity of the battery pack.

Modularity

Disruptive modularity is born from the concept of being able to use different types of batteries as long as they have the same chemistry and meet other parameters instructed by the manufacturer.

The concept was to generate a kind of case that grew or decreased in size depending on the shape of the battery, adapting to the different variaties that exist already, which could lead to reducing processes and saving resources in the remanufacturing area.

The integration of extensible elements fulfills the function of modeling itself to the shape of the battery, giving it a second layer of protection, allowing the user to manipulate it without risk of discharge and it has a snap system at the bottom to be attached to the reticle in the shell.

The modulation consists of an extendable and retractable chassis to adapt to the shape of the battery module. A handle at the top would allow the manipulation of the module without having any contact, in order to prevent risks.


NORSK-E


NORSK-E

Retractable snap for the incorporation of battery modules and other installations to the mesh in the compartment.

Product Storify

In the coming years, energy storage will become a necessity and a requirement. It will be crucial to accumulate energy from clean sources to reduce energy consumption and share it among users with similar needs. People will look for energy storage devices that are scalable, budget-friendly, and available in their area. As a result, ESS will become commonplace in technology and specialized stores, and it will be possible to find unique solutions in the market.

Norske is a product designed for individuals who want to have their own ESS at home or in frequented places. However, the options on the market are limited. By allowing users to purchase modules separately and incorporating USDA EV batteries, Norske becomes an attractive and scalable option compared to the new ESS.

This versatile ESS makes it easier to transport modules and use in remote areas. The physical interface makes it user-friendly in low-coverage areas. The system's modularity also simplifies maintenance without disrupting the ESS's operations.

John had always wanted to switch to solar power, but the upfront cost of a complete electrical system was too high to afford. So, he decided to take a different approach. He gradually built his power storage system as his energy needs and budget grew.
John researched and decided to go with NORSK-E, a reliable and affordable option for those on a budget. He started with a basic setup consisting of a few battery modules, which allowed him to power a few appliances in his home.
As time went on, John's energy needs grew, and so did his budget. He invested in more battery cells, which allowed him to power bigger appliances like his air conditioner and washing machine.
Despite the gradual build-up, John was proud of his power storage system. He had accomplished his goal of switching to a reliable power source, and he did it in an affordable and sustainable way.

Figure 25. Image open source, 2023 via https://www.pexels.com/photo/man-facing-solar-panels-1254997/

There was a couple who loved living in the mountains but faced a significant challenge. They needed a system to collect energy in a mountain without current or internet connection. So they did their research and found a system that would allow them to use it off-grid and take advantage of the functions of the physical interface to meet their energy needs, NORSK-E.
The system they chose was perfect for their situation, and they could generate enough energy to power their home and all of their devices. As a result, they could finally live in the mountains without worrying about running out of power or being disconnected from the world.
The physical interface of the system was easy to use and allowed them to monitor their energy usage and make adjustments as needed. They were impressed with how efficient the system was and how it allowed them to live a sustainable lifestyle without sacrificing comfort.
Thanks to this system, they were able to live in the mountains and enjoy all that nature had to offer without worrying about their energy needs. They were grateful for the technology that made it all possible and the peace of mind it brought them.

Figure 25. Image open source, 2023 via https://www.pexels.com/photo/man-in-brown-and-white-long-sleeve-shirt-carrying-black-backpack-walking-on-forest-8968496/

There was a person who had installed solar panels on their property. They had always felt proud of their decision to generate their own energy and reduce their carbon footprint. However, when they heard about the natural disaster that had struck the eastern area, they knew they had to do something to help.
As they watched news reports of families struggling without basic necessities like electricity, the person realized that their solar panels could make a difference. They knew they had two options: either continue to use their own energy and share the excess with the affected area, or take their solar modules to the eastern region so that the people there could have access to basic energy while the area was being reestablished.
After careful consideration, the person decided to share their resources. They contacted local organizations and worked with them to distribute the energy to the affected region. As the energy flowed through the network, the person felt a sense of pride and fulfillment knowing that they were helping others in need.
Over time, the area was reconnected to the main energy grid, and the person was able to return to their normal routine. But they never forgot the feeling of gratitude that came with being able to help others in a time of need. And they continued to generate their own energy, always ready to share it with those who might need it most.


Status
Sharing to the Grid
Battery
75%
Options
NORSK-E


NORSK-E


NORSK-E


NORSK-E
NORSK-E

5. Discussion

Branding

Establishing a brand is crucial in promoting the utilization of pre-owned EV batteries across various applications. In addition, this approach can aid in creating effective strategies to acquaint prospective users with the benefits of second-hand batteries, thereby instilling confidence in their usage.

To further this goal, educational campaigns could be designed to educate users on the proper usage of electric vehicle batteries and how this can impact their second life.

Furthermore, the brand can be utilized to foster collaboration among companies and stakeholders involved in the EV battery life cycle and establish agreements with energy supply organizations. This can promote a more transparent and unified approach towards the sustainable energy transition.

Functionality

The primary goal of the proposed concept is to ensure that everyone has access to affordable technology, regardless of their financial situation or intended use. This innovative system is designed to function as an ESS, utilizing repurposed EVBs to store clean energy and create an ecosystem that reduces the strain on the grid during peak usage. Furthermore, it can be tailored to suit both on-grid and off-grid applications, providing energy during high demand or shortage.

Design

The ESS design is founded on two principles - mesh and modularity. The mesh serves as a canvas where drum modules can be placed per the user's preference or system requirements. Furthermore, the mesh can accommodate additional components or add-ons produced over time, thanks to the snap that connects objects to it.

Modularity is a casing that expands or retracts depending on the battery module's size, creating a universal container that prevents the mass production of different components. This case offers protection to the modules, enables their installation in the ESS, and allows for module mobility if needed. By keeping the modules separate, individual maintenance can be performed without interrupting the ESS's use.

It has a physical and digital interface to ensure the concept's use in any context, though it's primarily intended for use in homes, cities, or suburbs. The physical interface is how the user connects with the ESS. Additionally, NFC reading is the most efficient means of ensuring user authentication for ESS use, much like home EV chargers.

Since the final product is a concept, bringing it to production and the market will take considerable effort. Therefore, it's primarily viewed as an approach some companies could take to enhance their used EVB appliances and a glimpse into features we might see in future scenarios.

Sustainability

The concept focuses on sustainability as the primary objective, incorporating a wide range of sustainability goals in the life cycle of EVBs. Collaboration between companies, while common in Norway, emphasizes the potential for stakeholder collaboration to extend the useful life of these batteries and generate products with high ecological, economic, and social impact.

The use of ESS is increasingly popular globally as a solution for storing clean energy. Energy storage is becoming a key concept in the green energy transition as it shifts from energy source storage to energy production storage. This shift in perspective encourages users to be more aware of energy consumption and resource use during the second life of EVBs and during their function in vehicles. Repurposing used EVBs generates new sources of employment, lengthens battery life expectancy, and optimizes recycling processes, making batteries more efficient and durable.

The opportunity to store energy provides an alternative to bringing resources to remote or infrastructure-lacking areas, primarily low-income communities. A closed-cycle production system using recycled materials could make the product more eco-friendly. The mesh structure allows battery modules to be separated and interchanged, extending the shell's life span and accommodating new technologies. Repurposing EVBs reduces environmental impact and mitigates the carbon footprint of battery production. A system that discharges battery packs safely and uses the remaining energy as a power source would be an ideal solution for retired batteries.

Prospects

Market

Did you know that used electric vehicle batteries can still be useful even after they are no longer suitable for powering electric vehicles? These batteries can store a significant amount of energy and provide an affordable solution for stationary energy storage. They can store excess renewable energy generated from solar or wind power and supply electricity during periods of high demand or when renewable energy sources are unavailable.

Used electric vehicle batteries can be integrated into the grid as a decentralized energy storage system, which helps balance the supply and demand of electricity while improving the overall reliability of the grid. This allows them to provide stability by storing excess energy during low demand and releasing it during peak periods.

Moreover, researchers can use these batteries for research and development purposes. They can study these batteries' performance, degradation patterns, and aging characteristics to improve battery technologies, enhance their lifespan, and optimize their use in various applications.

Emerging technologies

Supercapacitors are currently being tested for integration into electric vehicles (EVs), potentially improving performance while reducing energy density and extending the lifespan of EV batteries. However, it is estimated that this may impact the usage of existing EV batteries, allowing them only to be used up to 50-60% of their initial capacity during their first life.

Automating the repurposing and recycling process is expected to reduce the cost of used EV batteries while minimizing risks and optimizing the collection of materials and resources from the batteries in precise workspaces.

In addition, new battery technologies are being researched that require fewer raw materials and utilize less hazardous chemistries. These technologies enhance the performance of both the vehicles and the battery pack itself, potentially delaying the retirement of existing batteries and allowing companies to adapt to the new technologies.

Economy

Did you know that electric vehicle batteries that are no longer in use can be repurposed for smaller-scale power systems known as microgrids? These systems can function independently or cooperate with the primary power grid, making them especially useful in island communities or remote areas lacking reliable electricity. By combining renewable energy generation with these used EV batteries, microgrids can provide clean and affordable power to these communities, paving the way for sustainable energy solutions.

Moreover, repurposed EV batteries have the potential to create new market niches in the energy industry, presenting opportunities for energy provider companies to lease them out and make them more affordable for consumers. These companies can also maintain these devices as they already have field experts and even purchase energy from users when necessary. This outlook could also lead to new business models working alongside company partnerships.

As energy storage systems (ESS) use in households and industrial applications continues to rise, repurposed EV batteries could seize a significant market niche if prices become competitive with new applications. However, their capacity may be limited or reduced. Incorporating used EV batteries into different applications can help prolong their lifespan, reduce waste, and maximize the value derived from these batteries throughout their lifecycle.

Uncertainties

Renewable energy sources can create instability in the electrical grid, leading to increased prices. Companies may take advantage of this situation by raising the prices of Energy Storage System (ESS) appliances or devices that store energy.

In some countries, the energy industry is monopolized by two or three companies manipulating prices. This practice discourages people from using other energy sources or integrating ESS into the grid.

The variety of batteries continues to increase, and the aim is to increase it even more by 2030. This could lead to some refurbishment companies specializing in certain types of chemistry or battery brands, creating gaps in the market that could be optimized if battery standardization is achieved.

As the final product is a test, only the risk of discharge was evaluated. Further research is required to determine if it is possible to manipulate the modules safely. The concept of users building their battery should be considered, as it could save money on production stages, installment, and maintenance. This is especially relevant in the 2030 scope, where ESS is expected, and buying them in electronic stores should be normalized.

The hesitancy between stakeholders regarding the recycling vs. reuse of Electric Vehicle Batteries (EVBs) has increased in recent years. However, optimizing raw material usage means that more than one battery pack can be produced with materials recovered from a retired EVB.

The lack of automation in the repurpose industry makes second-life EVB applications as expensive as a new battery pack. Although recycled materials may be used in repurposed EVB applications, there is no assurance of their functionality and safety when holding battery modules.

Conclusions

Upon considering the current state of the market for second-hand electric vehicle (EV) batteries, it becomes evident that there is ample room for improvement. The market remains relatively new, with limited options available to consumers and a lack of standardization across the industry. These factors have significant implications for the sustainability of the entire EV life cycle.

Alternative uses for EV batteries are crucial to reducing the environmental impact caused by their production. Reusing batteries presents an opportunity to extend their lifespan and prevent early disposal. It also provides time to optimize recycling processes and halt the production of new batteries that were initially required for second uses.

Rather than viewing reusing and recycling as opposing strategies, a combination of both should be integrated into the end-of-life of EV batteries. Reusing can extend the battery's lifespan and provide the recycling industry with time to optimize the extraction of critical raw materials from batteries. Recycling is critical to recover the remaining raw materials and help reduce the extraction of new materials that may soon be in short supply.

A crucial question is who will be responsible for collecting and recovering batteries when their state of health indicates that they can no longer operate in their second-life activity. This also opens up the possibility of creating new market niches or business models based on repurposed battery activities, including energy provider companies.

The concept evaluates the proposal for second-use EV battery applications that could be versatile in other contexts. It aims to address the dilemma of the industry's rapid growth and worldwide adaptation, which could rely on alternative contexts, such as developing countries, and accessibility for those who cannot afford new ones. The model should be replicable, allowing users to invest based on their budget, creating equity in the green energy transition, and making energy affordable and accessible to everyone.

The possibility of interchangeable battery modules could expand the spectrum of transportable energy, giving users access to how they might want to use part of the stored energy or share it in other places.

Future work

To efficiently bring a concept to production or research prototyping, utilizing pre-made electrical cabinets or compartments that meet the necessary shell parameters would be a great solution. Additionally, a mesh concept could be created via a deep drawing process.

A universal adaptor for battery connectors, similar to those in mobile chargers, could be implemented with an adaptable modular design. Also, it is crucial to implement a short-term information and user education strategy to familiarize individuals and communities with EV batteries as a solution for daily activities.

Prototyping is necessary to evaluate the proposed concepts. Sharing the final product with potential future users for feedback on its potential market impact, given the speculative design methodology used, would be beneficial.

Developing a transitional strategy with short, mid, and long-term goals would aid in adapting the used batteries to various contexts and replicating successful models worldwide. User-focused scenarios could also be developed to evaluate the concept's alignment with industry needs and requirements.

Presenting the project and concept to a broader range of stakeholders would provide valuable feedback and insights. Moving towards a product stage with production emphasis would allow for evaluation in both low and high-volume scenarios. Collaboration with battery production experts would aid in integrating different modularities into the same system while considering other variables.

Lastly, a production strategy should be developed to evaluate low-cost solutions for providing energy access to remote communities. Further user research would be necessary to introduce the EVB into the market and encourage individuals to choose sustainable solutions over new ones.

Deviation from the assignment

The wait for a response from experts caused the project to pause for a week or two in search of feedback and insights. In turn, the number of experts who responded was relatively low compared to expectations.

Some experts were hesitant to share information about progress on the subject because it could contain sensitive or critical details that differentiate them in the market.

Although they ended up opting for the speculative design methodology, one of the goals was to be able to generate a prototype of the alternative for the use of used EV batteries because it was determined to create concepts to be able to analyze different options that could end up in proposals or features that could be adapted to future designs. Therefore, no production aspects or usability issues were looked at.

The risk and complexity of handling battery modules made the experts deny access to them, which could have been repeated in a more detailed analysis.

In searching for state of the art or products on the market, the information is limited, so it was necessary to speculate on technical and practical aspects.

Not having a specific user, it was difficult to establish a filter on the future user and how to approach them in order to obtain insights or feedback from them on how they see the concept, if they would find it interesting to acquire it and needs that grow in the face of the energetic transition.

Evaluation

Experts

The experience with the experts during the development of the thesis was very fluctuating, many of them did not answer and others did not find the project interesting due to the lack of technical characteristics that most experts expected. The experts who answered and were during the process showed interest but always maintained their technical and industrial position. To some extent it was important to know the position of the stakeholders regarding future energy solutions, but they were cautious when talking about conceptual aspects. or subjective.

Supervisors

My supervisors were always aware of my progress with the project, although sometimes the feedback was very subjective; this helped me a lot to establish the speculative methodology and help me look at aspects of how the concept could be visualized, tools to enhance the project, and ways to obtain information. In addition, they were always open to listening to my progress and helping me correct my route when I deviated from the objectives or felt slowed down.

Although they were always available, I didn't use as much supervision as I could want, but it was more by personal decision, which I regret as I feel I could have gone deeper into the task with further help.

Own effort

Although the outcome has interestinc oncepts, I wish I could have opted more into product design and prototyping. Although speculative design is useful for exploring emerging trends and potential technologies for future products, I didn't feel confident using it, and it was a struggle to stay motivated while waiting for expert feedback and user input.

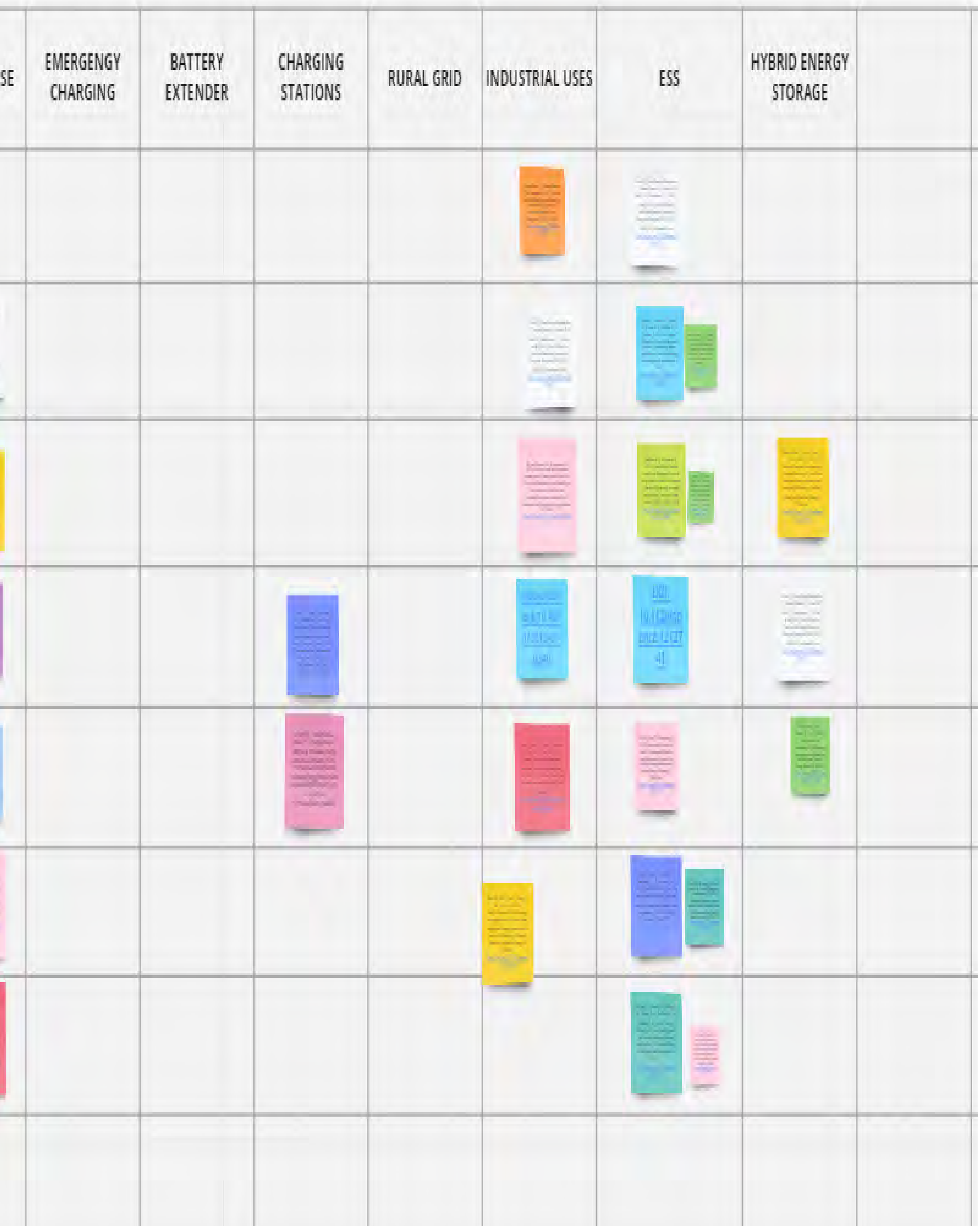
However, it was intriguing to investigate alternative tools to analyze the behavior of a hypothetical product since there were no technical specifications or an actual product to work with.

References

AGENCY, I. E. 2022. Global EV Outlook 2022.
FARIA, R., MARQUES, P., GARCIA, R., MOURA, P., FREIRE, F., DELGADO, J. & DE ALMEIDA, A. T. 2014. Primary and secondary use of electric mobility batteries from a life cycle perspective. Journal of Power Sources. Elsevier BV.
GIRARDI, P., GARGIULO, A. & BRAMBILLA, P. C. 2015. A comparative LCA of an electric vehicle and an internal combustion engine vehicle using the appropriate power mix: the Italian case study. The International Journal of Life Cycle Assessment, 20, 1127-1142.
INC., R. 2021. EV Consumer Behavior; June 2021 Electric Vehicle council. Fuel Institute.
KAMPKER, A., HEIMES, H. H., ORDUNG, M., LIENEMANN, C., HOLLAH, A. & SAROVIC, N. 2016. Evaluation of a Remanufacturing for Lithium Ion Batteries from Electric Cars. World Academy of Science, Engineering and Technology, International Journal of Mechanical and Mechatronics Engineering, 3, 1929-1935.
KOTAK, Y., MARCHANTE FERNÁNDEZ, C., CANALS CASALS, L., KOTAK, B. S., KOCH, D., GEISBAUER, C., TRILLA, L., GÓMEZ-NÚÑEZ, A. & SCHWEIGER, H.-G. 2021. End of Electric Vehicle Batteries: Reuse vs. Recycle. Energies, 14, 2217.
MELANÇON, S. 2022. ELECTRIC VEHICLE BATTERY CELLS EXPLAINED [Online]. LASERAX: LASERAX. Available: https://www.laserax.com/blog/ev-battery-cell-types [Accessed 10/09/2022 2022].
Mirzaei Omrani, M., & Jannesari, H. (2019). Economic and environmental assessment of reusing electric vehicle lithium-ion batteries
for load leveling in the residential, industrial and photovoltaic power plants sectors. Renewable and Sustainable Energy Reviews, 116,
109413. https://doi.org/https://doi.org/10.1016/j.rser.2019.109413
Neubauer, J., & Pesaran, A. (2011). The ability of battery second use strategies to impact plug-in electric vehicle prices and serve
utility energy storage applications. Journal of Power Sources, 196(23), 10351-10358. https://doi.org/https://doi.org/10.1016/j.jpowsour.
2011.06.053
Neubauer, J. P., A. Williams, B. Ferry, M. et al. (2012). A Techno-Economic Analysis of PEV Battery Second Use: Repurposed-Battery
Selling Price and Commercial and Industrial End-User Value. S. T. Paper.
Pitron, G. (2020). The rare metals war : the dark side of clean energy and digital technologies (B. Jacobsohn, Trans.). Scribe.
Sathre, R., Scown, C. D., Kavvada, O., & Hendrickson, T. P. (2015). Energy and climate effects of second-life use of electric vehicle batteries
in California through 2050. Journal of Power Sources, 288, 82-91. https://doi.org/10.1016/j.jpowsour.2015.04.097
Saxena, S., Le Floch, C., MacDonald, J., & Moura, S. (2015). Quantifying EV battery end-of-life through analysis of travel needs with
vehicle powertrain models. Journal of Power Sources, 282, 265-276. https://doi.org/https://doi.org/10.1016/j.jpowsour.2015.01.072
Su, H., Yang, J., Du, X., Wang, Z., & Li, Y. (2020). Configuration of community hybrid energy storage system based on retired power
battery. Energy Reports, 6, 934-942. https://doi.org/https://doi.org/10.1016/j.egyr.2020.11.106

Apendix

Battery Life SOH // Usability	EV VEHICLES	HYBRID VEHICLES	BOATS	SMART/MICRO MOBILITY	HOUSEHOLDS	TRASPORTABLE ENERGY	SMART GRID	DISTRIC U
100 %								
90 %								[illegible]
80 %			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
70 %		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
60 %		[illegible]		[illegible]	[illegible]		[illegible]	[illegible]
50 %	[illegible]	[illegible]					[illegible]	[illegible]
40 %					[illegible]		[illegible]	[illegible]
30 %							[illegible]	[illegible]
20 %					[illegible]			


EMERGENGY CHARGING
BATTERY EXTENDER
CHARGING STATIONS
RURAL GRID
INDUSTRIAL USES
ESS
HYBRID ENERGY STORAGE

Matrix

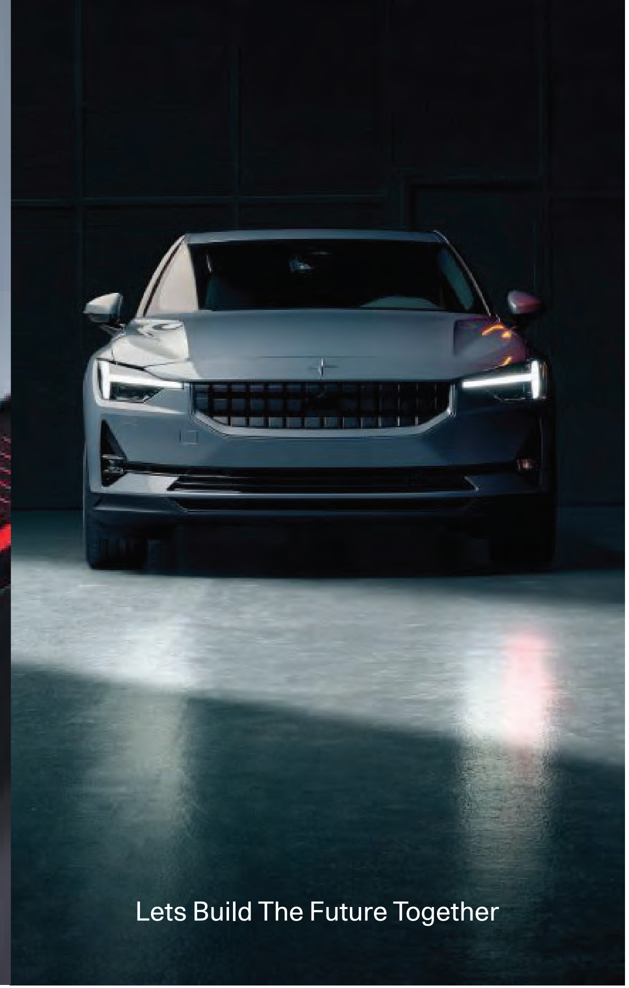
Transparency

We plan to achieve our goal by focusing our efforts on the areas of climate neutrality, circularity, transparency and inclusion.

Colors available

Polestar

ALV Battery Pack Household Design
Repurpose strategy



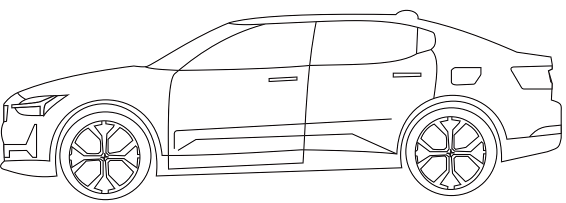
Circularity

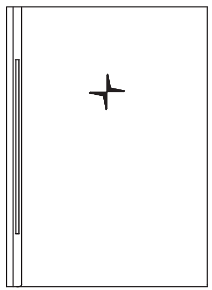
Design that evolves for you

Our goal t o build sustainable t ransitions has taken the Vehicle to Grid (V2G) strategy a step further.

Now when you need to change the battery in your **Polestar** you can choose to convert it into a Household battery.

Safer Cleaner Simpler





24/7

Secure backupR

echarge with grid or clean energy

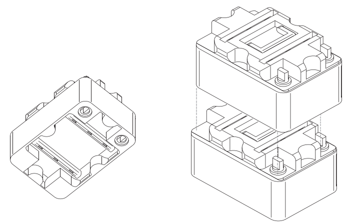
Charges in low peak hours

You decide when and how to use it

TAKE THE POWER YOU NEED EVERYWHERE!

ELKJOP

Norsk-e 12 kWh Battery Module from EV



This battery modules are the perfect balance between sustainability and practicability. It can be charge connected to your grid, or even power your house up to one day without interruption*. The stackability properties let you build your own battery grid, based on your needs and budget, just placed them one on top the other. Lightweight and size were taken into account so it can be carry-on to your daily activities if needed.

*Based on the average household consume of 9kWh per day / Student concept mockup

SPECIFICATIONS

9 Kwh battery modules from used electric vehicles.

12 Kilograms per Module.

Easy compatibility between modules.

Stackability: Build your own grid base on your needs.

Battery charge status light sensor

FROM 7500;

FOR MORE INFORMATION VISIT
WWW.ELKJOP.NO/GJENBRUKBATTERI
OR ONE OF OUR MEGASTORES.

Norsk-e Battery pack from EV

SOLCELLE & ENERGI

Refurbished battery pack from an EV with 55 kWh capacity, with the capacity to power up a cabin with essential electrical appliances uninterrupted for 10 days without charging. Includes 3 modules that can be detached from the main battery back and used in other activities, conditioned backpack with energy converter that allows use in outdoor activities or tools that require energy power.

Inbuilt outlets to power your tools or devices and used them on the go.

Special compartment develop to carry and use the battery module everywhere.

Repurpose
Electric
Battery

Converter
Inbuilt
Backpack

Modularity
to take advantage
of the energy produced

hyttetorget

Student concept mockup

NTNU

Norwegian University of
Science and Technology